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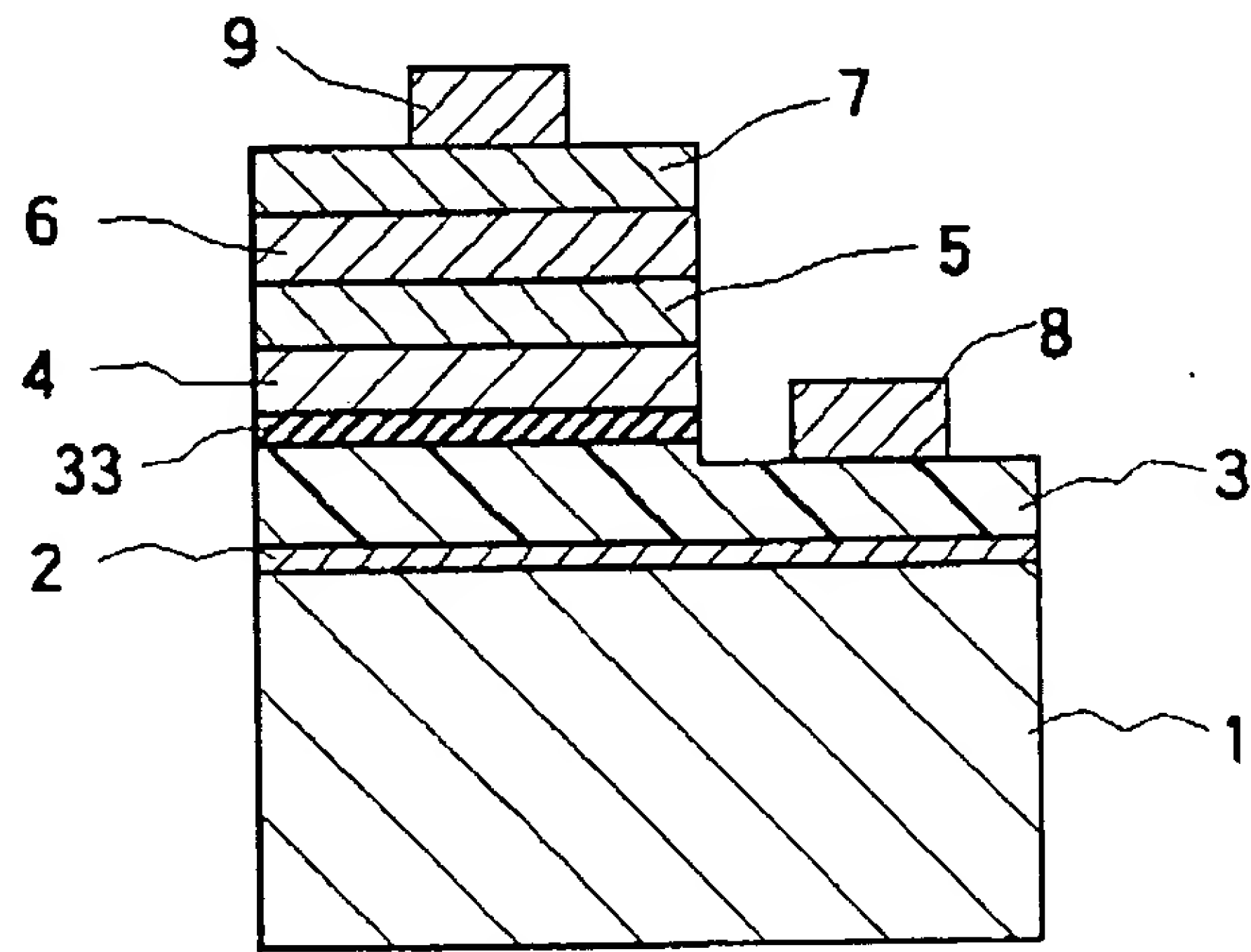
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(54) 【発明の名称】 窒化ガリウム系化合物半導体発光素子

(57) 【要約】

【目的】 活性層より均一な発光を得て、素子の光度、出力を向上させ、また発光素子のV_fをさらに低下させて、発光効率を向上させる。

【構成】 少なくともn型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記n型層は基板側に形成された第一のn型層3と、その第一のn型層3に接して活性層5側に形成されて、第一のn型層3よりも電子キャリア濃度が大きい第二のn型層33とを含む。



【特許請求の範囲】

【請求項1】 少なくともn型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記n型層は基板側に形成された第一のn型層と、その第一のn型層に接して活性層側に形成されて、第一のn型層よりも電子キャリア濃度が大きい第二のn型層とを含むことを特徴とする窒化ガリウム系化合物半導体発光素子。

【請求項2】 前記第二のn型層が少なくともインジウムを含む窒化ガリウム系化合物半導体 ($\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}\text{N}$, $0 < x$, $0 \leq y$, $x+y \leq 1$) よりなることを特徴とする請求項1に記載の窒化ガリウム系化合物半導体発光素子。

【請求項3】 前記第二のn型層は互いに組成の異なる窒化ガリウム系化合物半導体層が2層以上積層された多層膜よりなることを特徴とする請求項1または請求項2に記載の窒化ガリウム系化合物半導体発光素子。

【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明はレーザダイオード (LED)、発光ダイオード (LED) 等の発光素子に使用される窒化ガリウム系化合物半導体 ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 \leq a$, $0 \leq b$, $a+b \leq 1$) よりなる発光素子に関する。

【0002】

【従来の技術】 現在、実用化されている光度1cdの青色LEDは窒化ガリウム系化合物半導体 ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 \leq a$, $0 \leq b$, $a+b \leq 1$) よりなり、図1に示す構造を有している。それは、サファイアよりなる基板1の表面に、GaNよりなるバッファ層2と、GaNよりなるn型層3と、AlGaNよりなるn型クラッド層4と、InGaNよりなる活性層5と、AlGaNよりなるp型クラッド層6と、GaNよりなるp型コンタクト層7とが順に積層されたダブルヘテロ構造である。この青色LEDは順方向電流 (If) 20mAにおいて、順方向電圧 (Vf) 3.6V、ピーク発光波長450nm、光度1cd、発光出力1.2mWと、青色LEDでは過去最高の性能を示している。

【0003】 前記構造のLEDにおいて、基板1はサファイアの他にZnO、SiC、GaAs、Si等の材料が使用可能であるが、一般的にはサファイアが用いられる。バッファ層2はGaNの他、GaAlN、AlN等が形成される。n型コンタクト層3、n型クラッド層4は窒化ガリウム系化合物半導体にSi、Ge、Sn、C等のn型ドーパントをドーブした窒化ガリウム系化合物半導体で形成される。また、n型コンタクト層3、n型クラッド層4は、このように二層に分けなくても単一のn型層として、クラッド層およびコンタクト層として作用させてもよい (つまり、いずれかの層を省略できる)。活性層5は少なくともインジウムを含む窒化ガリ

ウム系化合物半導体よりなり、ノンドープ、Zn、Mg、Cd、Be等のp型ドーパント及び/またはn型ドーパントがドーブされている。p型クラッド層6、p型コンタクト層7は窒化ガリウム系化合物半導体にp型ドーパントをドーブした後、400℃以上でアニーリングすることにより、p型とされている。また、p型クラッド層6、p型コンタクト層7は、単一のp型層として、クラッド層およびコンタクト層として作用させてもよい (n層と同様にいずれかの層を省略可能)。

【0004】

【発明が解決しようとする課題】 窒化ガリウム系化合物半導体の場合、他のGaAs、GaP、AlInGaP等のIII-V族化合物半導体に比べて、一般に電流が均一に広がりにくいという性質を有している。そこで図1のような構造のLED素子を実現した場合、n層から活性層に供給される電子の流れが、抵抗の低い箇所に集中してしまうという問題がある。図2は電流の集中による活性層の発光を模式的に示している。これは、n型コンタクト層3の負電極8より供給された電子が、図2の矢印に示すように、p型コンタクト層7の正電極9と、n型コンタクト層3の負電極8との間の抵抗が低くなるように、いちばん近い距離を流れることにより、活性層5が網掛け部で示すように部分的に強く発光していることを表している。このように、電子がn型コンタクト層3に均一に広がらないと、活性層5から均一な発光が得られないという欠点がある。

【0005】 また、上記構造のLEDはVf3.6Vと、従来のMIS構造の窒化ガリウム系化合物半導体よりなる青色LEDに比べて、5V以上Vfを低下させた。これはp-n接合による発光を示すものであるが、Vfについてもまだ改良する余地があり、さらなるVfの低下が望まれている。

【0006】 従って本発明はこのような事情を鑑みてなされてものであり、その目的とするところは、ダブルヘテロ、シングルヘテロ等、少なくともn型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、まず第一に活性層より均一な発光を得て、素子の光度、出力を向上させることにあり、第二にVfをさらに低下させて、発光効率を向上させることにある。

【0007】

【課題を解決するための手段】 我々はn型層にさらにキャリア濃度の高い層を介在させることにより、上記問題が解決できることを見いだした。即ち、本発明の窒化ガリウム系化合物半導体発光素子は、少なくともn型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記n型層は基板側に形成された第一のn型層と、その第一のn型層に接して活性層側に形成されて、第一のn型層よりも電子キャリア濃度が大きい第二のn型層とを含むことを特徴

とする。

【0008】本発明の一実施例の発光素子の構造を図3に示す。基本的な構造は図1に示す発光素子とほぼ同じであるが、第一のn型層であるn型コンタクト層3に接して、活性層5側にその第一のn型層3よりも電子キャリア濃度が大きい新たな第二のn型層33を形成している。基板1、バッファ層2、n型コンタクト層3、n型クラッド層4、活性層5、p型クラッド層6、p型コンタクト層7等は窒化ガリウム系化合物半導体で形成され、n型コンタクト層3とn型クラッド層4とを単一のn型層とすることもでき、またp型クラッド層6とp型コンタクト層7とを単一のp型層とすることもできる。

【0009】本発明の発光素子において、結晶性に優れた窒化ガリウム系化合物半導体層を成長させるには、基板1にサファイアを好ましく用い、バッファ層2にGa₂N₃、またはAlNを成長させ、10オングストローム～0.5μmの膜厚で形成することが好ましい。

【0010】活性層5と基板1との間に形成する第一のn型層は、n型コンタクト層3としては通常1μm～5μmの膜厚で形成し、その表面にn型クラッド層4を形成する場合には50オングストローム～1μmの膜厚で成長する。但し、前記のように、このn型クラッド層4は特に形成しなくてもよい。窒化ガリウム系化合物半導体としてはGa₂N₃、AlGa₂N₃が好ましく、最も好ましくはGa₂N₃とする。なぜならGa₂N₃、AlGa₂N₃はノンドーパあるいはn型ドーパントをドーピングして容易にn型となり、ドーパントにより電子キャリア濃度を制御することが容易である。さらにAlGa₂N₃よりも単一層で結晶性のよい厚膜を形成するにはGa₂N₃が成長しやすい。例えば、サファイアを基板としてn型層とp型層とを順に積層した素子を実現した場合、n型コンタクト層3の電極8を設けるため、p型層をエッチングにより取り除き、n型コンタクト層3を露出させる必要があるが、単一層で厚膜が形成できると、エッチング深さの遊度があるので、実際の素子を実現する際に非常に好都合である。

【0011】次に、活性層5は、通常50オングストローム～0.5μmの膜厚で成長し、InGa₂N₃とすることが好ましい。InGa₂N₃はインジウムの混晶比によりバンド間発光を利用して発光素子の発光波長を紫～緑色まで容易に変化させることができ、さらにn型、p型のドーパントをドーピングして発光中心とすることも容易である。さらにInのGaに対する混晶比(In/Ga)は0.5以下であることが好ましい。0.5より多いInGa₂N₃は結晶性がよくないので実用的な発光素子を得ることが困難となる傾向にある。最も優れた活性層としてはn型ドーパントと、p型ドーパントとがドーピングされてn型とされ、Gaに対するIn混晶比が0.5以下のInGa₂N₃を活性層とすることが好ましい。

【0012】活性層5の上に成長するp型層もGa₂N₃、

AlGa₂N₃が好ましく、p型クラッド層6は50オングストローム～1μmの膜厚で形成し、pコンタクト層7は50オングストローム～5μmの膜厚で成長する。但し、このp型クラッド層6は特に形成させなくてもよい。窒化ガリウム系化合物半導体としてはGa₂N₃、AlGa₂N₃を好ましく形成する、これらは単一層で結晶性のよい厚膜が成長しやすく、またp型ドーパントをドーピングして400℃以上でアニールすると容易にp型となる傾向にある。

【0013】

【作用】図4に、図3の発光素子における第一のn型層であるn型コンタクト層3から、活性層5に供給される電子の流れを模式的に示す。これは、n型コンタクト層3から供給される電子が、矢印に示すように電子キャリア濃度の大きい第二のn型層33中を通って均一に広がることにより活性層5を均一に発光させることを示している。このように第一のn型層に接して、その第一のn型層よりも電子キャリア濃度の大きい第二のn型層33を活性層側に形成すると、電子が第二のn型層33中に均一に広がるので、活性層5から均一な面発光が得られる。

【0014】第二のn型層33はインジウムを含むIn_xAl_yGa_{1-x-y}N (0<X, Y≤0) とすることが好ましく、特に好ましくはInのGaに対する混晶比(In/Ga)が0.5以下のInGa₂N₃とするのがよい。なぜなら、Inを含む窒化ガリウム系化合物半導体の方が、含まないものよりも電子キャリア濃度の大きい層を形成しやすく、またInを含む結晶は、含まない結晶に比べて結晶が柔らかく、転位などの結晶欠陥を吸収しやすい。そのため基板上にAlGa₂N₃、Ga₂N₃等の格子整合していない第一のn型層3を成長させた場合、その第一のn型層3の結晶欠陥を第二のn型層33で緩和することが可能であるからである。

【0015】第二のn型層33の電子キャリア濃度は1×10¹⁸/cm³～1×10²²/cm³の範囲に調整することが好ましく、また第二のn型層33よりも電子キャリア濃度の小さい第一のn型層は1×10¹⁶/cm³～1×10¹⁹/cm³の範囲に調整することが好ましい。これらの電子キャリア濃度は、前記のように第二のn型層にSi、Ge、Sn、C等のn型ドーパントをドーピングすることにより調整可能である。第二のn型層33の電子キャリア濃度が1×10¹⁸/cm³よりも小さいと、電子を広げる作用が得られにくくなり均一な活性層の発光が得られにくく、1×10²²/cm³よりも大きいと結晶性が悪くなり、発光素子の性能に悪影響を及ぼす恐れがある。また第一のn型層についても電子キャリア濃度が1×10¹⁶/cm³よりも小さいと活性層自体の発光が得られにくく、また1×10¹⁹/cm³よりも大きいと1μm以上の厚膜を形成した際に結晶性が悪くなる傾向にあり、素子の出力を低下させる恐れがあるからである。

【0016】第二のn型層33の膜厚は通常10オングストローム～1μmの膜厚で、さらに好ましくは50オングストローム～0.3μmの膜厚で形成することが好ましい。10オングストロームよりも薄いと結晶性が不十分となるので、電子を広げる作用が得られにくくなり均一な活性層の発光が得られにくく、また1μmよりも厚いと結晶欠陥が第二のn型層中に発生しやすくなり結晶性が悪くなるので、発光素子の性能を悪化させる恐れがある。

【0017】さらに、第二のn型層33はIn、Ga、Alの組成比が異なる窒化ガリウム系化合物半導体を2層以上積層した多層膜としてもよい。多層膜とする際の各層の膜厚も10オングストローム～1μm、さらに好ましくは50オングストローム～0.3μmの多層膜とすることが好ましい。この第二のn型層33を多層膜とすることにより、第一のn型層の結晶欠陥を多層膜層で止めると共に、格子整合していない窒化ガリウム系化合物半導体を積層した際の結晶中の歪を緩和して、結晶性に優れた半導体層を成長できるので発光素子の出力を向上させることができる。

【0018】次に、図5は本発明の他の実施例の発光素子の構造を示す模式断面図である。これは第一のn型層3に形成された負電極8と基板1との間に、第二のn型層33が形成され、第二のn型層33と負電極8との距離が接近していることを示している。本来であれば、電極8をキャリア濃度の大きい第二のn型層33の表面に形成できれば、例えば図4と比較して、電子がキャリア濃度の大きい第二のn型層33を通して流れるので、発光素子のVfを低下させることができる。しかしながら、サファイアのような絶縁性基板を用いた場合、エッチングを第二のn型層33で止めることが生産技術上困難であるため、図5のように第二のn型層33と負電極8との距離を短くして、電極8から注入された電子がキャリア濃度の大きい第二のn型層33を通ることにより、Vfを低下させることが可能となる。

【0019】さらに、サファイアを基板とし、そのサファイア基板の表面に少なくともn型層と、活性層と、p型層とが順に積層されて、そのp型層と活性層とがエッチングされて露出されたn型層の表面に電極が形成される構造の発光素子においては、第二のn型層33を、n型層の電極形成面と基板との間に形成することにより効果的にVfを低下させることができる。なぜなら、SiC、ZnO、Si等の導電性基板の表面に窒化ガリウム系化合物半導体を成長した構造の発光素子であれば、n型層の電極は基板側に形成でき、n層側の電子は活性層に対し垂直に供給される。それに対し前記のようにサファイア基板を有する素子は、活性層に対し平行に供給される。垂直に供給される電子がn型層を移動する距離はせいぜい数μmであるのに対し、平行に供給される電子の移動距離は数十μm～数百μmもある。従って電子が

平行に供給される素子において、電子が平行に供給される第二のn型層のキャリア濃度を大きくすることにより、電子が移動しやすくなるのでVfを低下させることができる。

【0020】

【実施例】

【実施例1】MOVPE法により、2インチφのサファイアよりなる基板1の表面に、GaNよりなるバッファ層2を0.02μmの膜厚で成長させる。このバッファ層2の表面に第一のn型層として、Siをドーピングした電子キャリア濃度 $5 \times 10^{18} \text{ cm}^{-3}$ のn型GaNよりなるn型コンタクト層3を1μmの膜厚で成長させる。

【0021】次にn型コンタクト層3の表面に第二のn型層として、Siをドーピングした電子キャリア濃度 $1 \times 10^{20} \text{ cm}^{-3}$ のn型In0.1Ga0.9N層を0.05μmの膜厚で成長させる。

【0022】次に同じくSiをドーピングした電子キャリア濃度 $5 \times 10^{18} \text{ cm}^{-3}$ のGaNよりなるn型コンタクト層3'を3μmの膜厚で成長させる。

【0023】n型コンタクト層3'の表面に、Siをドーピングした電子キャリア濃度 $1 \times 10^{18} \text{ cm}^{-3}$ のn型Al0.2Ga0.8Nよりなるn型クラッド層を0.1μmの膜厚で成長させ、その上にSiとZnドーピングn型In0.1Ga0.9Nよりなる活性層5を0.1μmと、MgドーピングAl0.2Ga0.8Nよりなるp型クラッド層6と、MgドーピングGaNよりなるp型コンタクト層7を順に成長させて積層する。

【0024】以上のようにして得たウェーハをアニーリング装置に入れ、700℃でアニーリングして、p型クラッド層6およびp型コンタクト層7をさらに低抵抗なp型とした後、p型コンタクト層7の表面に所定の形状のマスクを形成し、p型コンタクト層側からエッチングを行い、n型コンタクト層3'を露出させる。

【0025】後は常法に従い、p型コンタクト層7に正電極9と、露出したn型コンタクト層3'に負電極8を形成した後、チップ状に分離して、図5に示すような構造の青色発光素子とした。この発光素子発光させたところ、活性層5から主発光波長450nmの均一な面発光が観測され、順方向電流(I_f)20mAにおいて、V_fは3.3Vであり、発光出力は1.8mWであった。

【0026】【実施例2】バッファ層2の表面に、第一のn型層として電子キャリア濃度 $1 \times 10^{18} \text{ cm}^{-3}$ のGeドーピングGaNよりなるn型コンタクト層3を1μmの膜厚で成長し、その表面に電子キャリア濃度 $5 \times 10^{20} \text{ cm}^{-3}$ のGeドーピングIn0.2Ga0.8Nよりなる第二のn型層を0.01μmの膜厚で成長させる。次に第二のn型層33の表面に同じく電子キャリア濃度 $1 \times 10^{18} \text{ cm}^{-3}$ のGeドーピングn型GaNよりなるn型コンタクト層3'を2μmと、電子キャリア濃度 $5 \times 10^{20} \text{ cm}^{-3}$ のGeドーピングn型In0.2Ga0.8Nよりなる第二のn型層

33' を $0.01\mu\text{m}$ と、電子キャリア濃度 $1 \times 10^{18}/\text{cm}^3$ の Ge ドープ n 型 GaN 層とを $1\mu\text{m}$ の膜厚で順に成長させる。

【0027】後は実施例 1 と同様にして n 型クラッド層 4、活性層 5、p 型クラッド層 6、p 型コンタクト層 7 を積層して、図 6 に示すような構造の青色発光素子とした。但し、図 6 に示すように、p 型コンタクト層 7 からのエッチング深さは n 型コンタクト層 3' までとし、負電極 8 は n 型コンタクト層 3' の表面に形成した。そして、この発光素子を発光させたところ、実施例 1 と同様

【0028】〔実施例 3〕バッファ層 2 の表面に、第一の n 型層として電子キャリア濃度 $1 \times 10^{18}/\text{cm}^3$ の Si ドープ Al_{0.1}Ga_{0.9}N よりなる n 型コンタクト層 3 を $3\mu\text{m}$ の膜厚で成長させる。次にその表面に、電子キャリア濃度 $1 \times 10^{20}/\text{cm}^3$ の Si ドープ In_{0.2}Ga_{0.8}N を $0.01\mu\text{m}$ と、電子キャリア濃度 $1 \times 10^{20}/\text{cm}^3$ の Si ドープ Al_{0.05}Ga_{0.95}N を $0.01\mu\text{m}$ と

【0029】次に第二の n 型層 33 の表面に、Si と Zn ドープ n 型 In_{0.1}Ga_{0.9}N よりなる活性層 5 を $0.1\mu\text{m}$ と、Mg ドープ Al_{0.2}Ga_{0.8}N よりなる p 型クラッド層 6 と、Mg ドープ GaN よりなる p 型コンタクト層 7 を順に成長させて積層する。つまり、実施例 1 の n 型クラッド層 4 を成長させない他は同様にして活性層 5、p 型クラッド層 6、p 型コンタクト層 7 を成長させる。後は実施例 1 と同様にしてエッチングを行い、図 3

【0030】〔比較例 1〕実施例 1 において、第二の n 型層 33 を成長させず、GaN コンタクト層を連続的に $4\mu\text{m}$ の膜厚で成長させる他は同様にして、図 1 に示すような構造の発光素子とした。この発光素子の活性層は、図 2 に示すように正電極 9 と、負電極 8 との間で強

く発光し、均一な発光を得ることができなかった。また $I_f 20\text{mA}$ において、 V_f は 3.6V 、発光出力 1.2mW であった。

【0031】

【発明の効果】以上説明したように、本発明の発光素子は全て活性層から均一な面発光を得て発光出力の向上した素子を実現できる。また、実施例 1、2 のように第二の n 型層 33 を負電極 8 と、基板 1 との間に形成した発光素子は、明らかに V_f が低下している。また実施例 3 は第二の n 型層が基板と負電極との間にないので、 V_f は低下に関しては影響が少ないが、第二の n 型層を多層膜としているので、活性層、p 型クラッド層、p 型コンタクト層の結晶欠陥が少なくなり、発光出力が向上している。このように本発明の発光素子はキャリア濃度の大きい第二の n 型層が第一の n 型層に接して活性層側に形成されていることにより、均一な面発光を得て、発光出力の向上した素子を実現することができる。

【図面の簡単な説明】

【図 1】 従来の発光素子の構造を示す模式断面図。

【図 2】 図 1 の発光素子の発光状態を示す模式断面図。

【図 3】 本発明の一実施例の発光素子の構造を示す模式断面図。

【図 4】 図 3 の発光素子の発光状態を示す模式断面図。

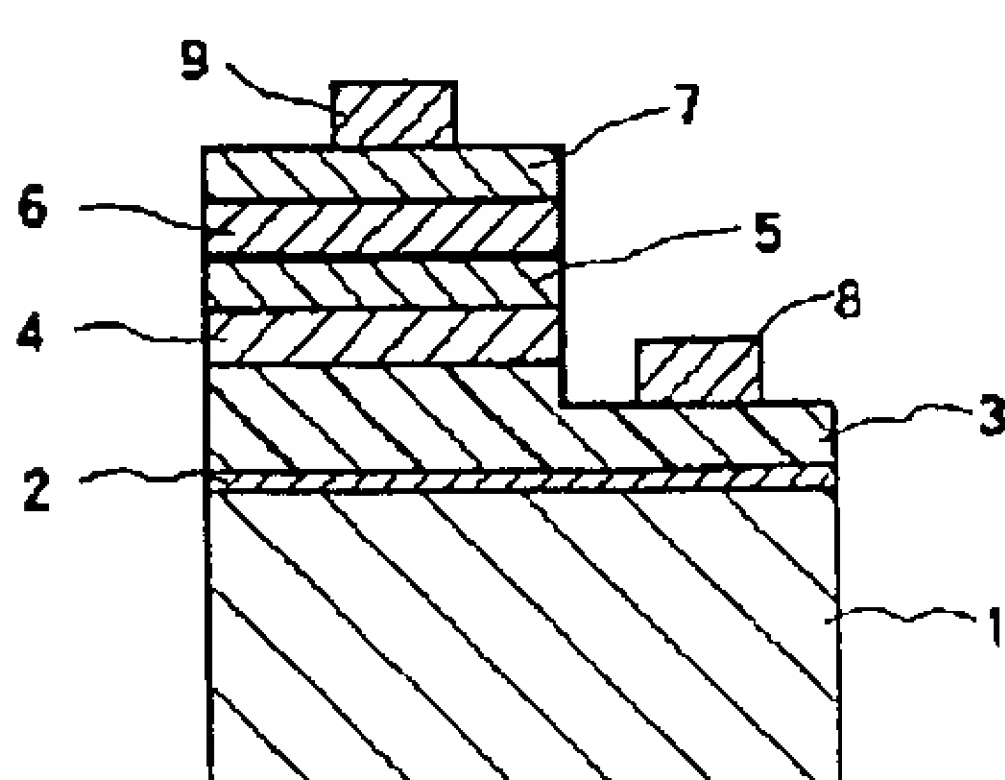
【図 5】 本発明の他の実施例の発光素子の発光状態を示す模式断面図。

【図 6】 本発明の他の実施例の発光素子の構造を示す模式断面図。

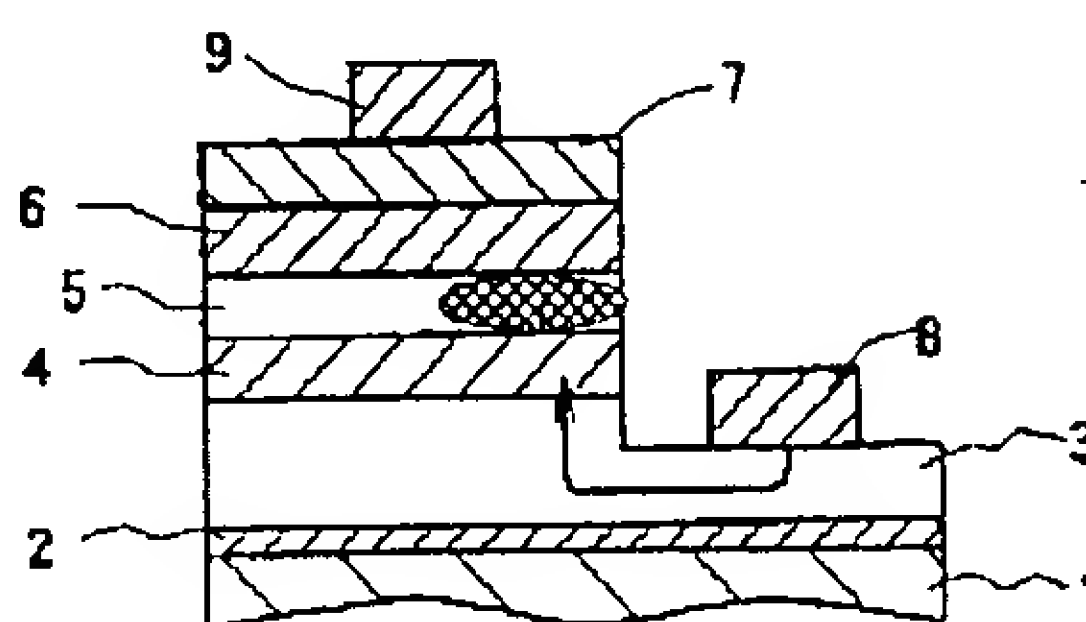
【符号の説明】

1 基板	2 バッファ層
4 n 型クラッド層	5 活性層
6 p 型クラッド層	7 p 型コンタクト層
8 負電極	9 正電極
3、3'、3'' 第一の n 型層 (n 型コンタクト層)	
33、33' 第二の n 型層	

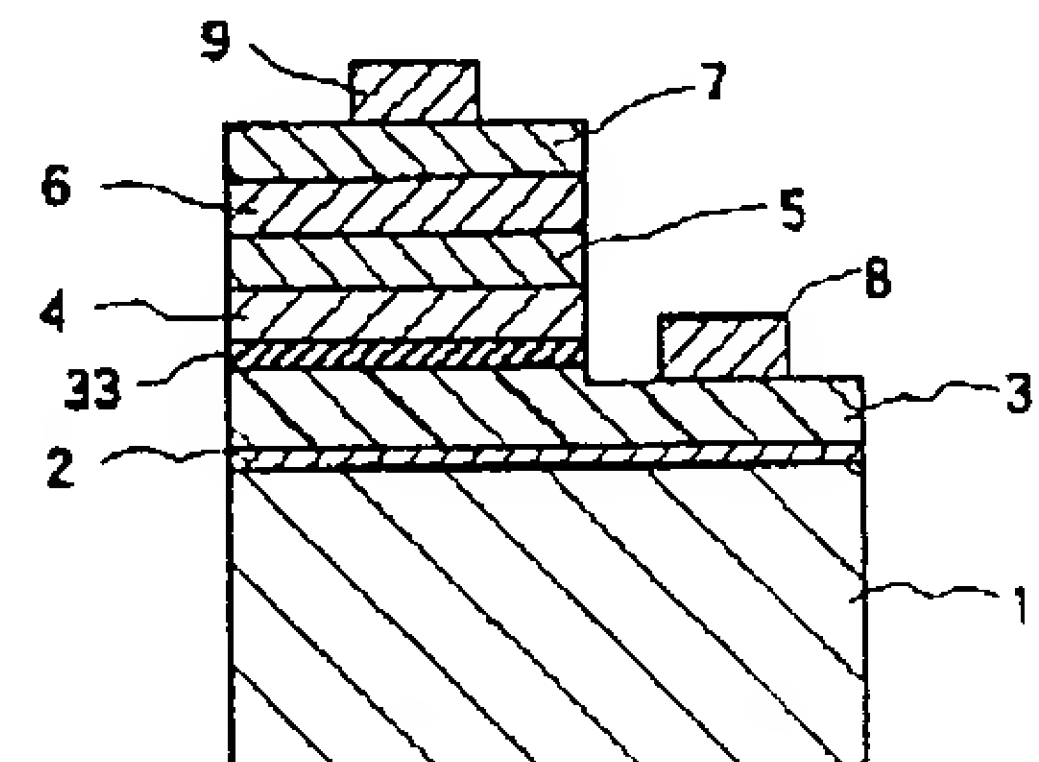
【図 1】



【図 2】

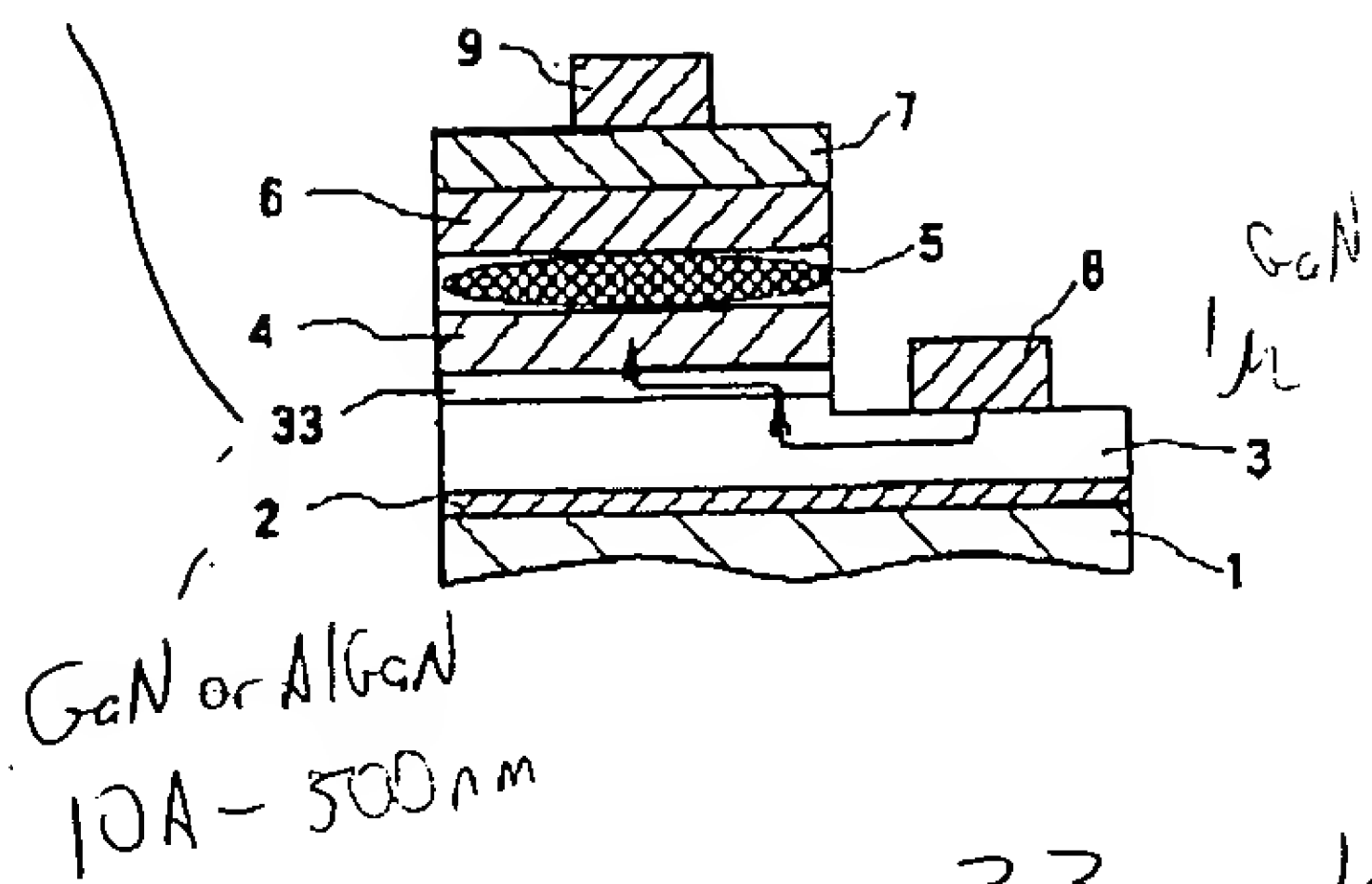


【図 3】

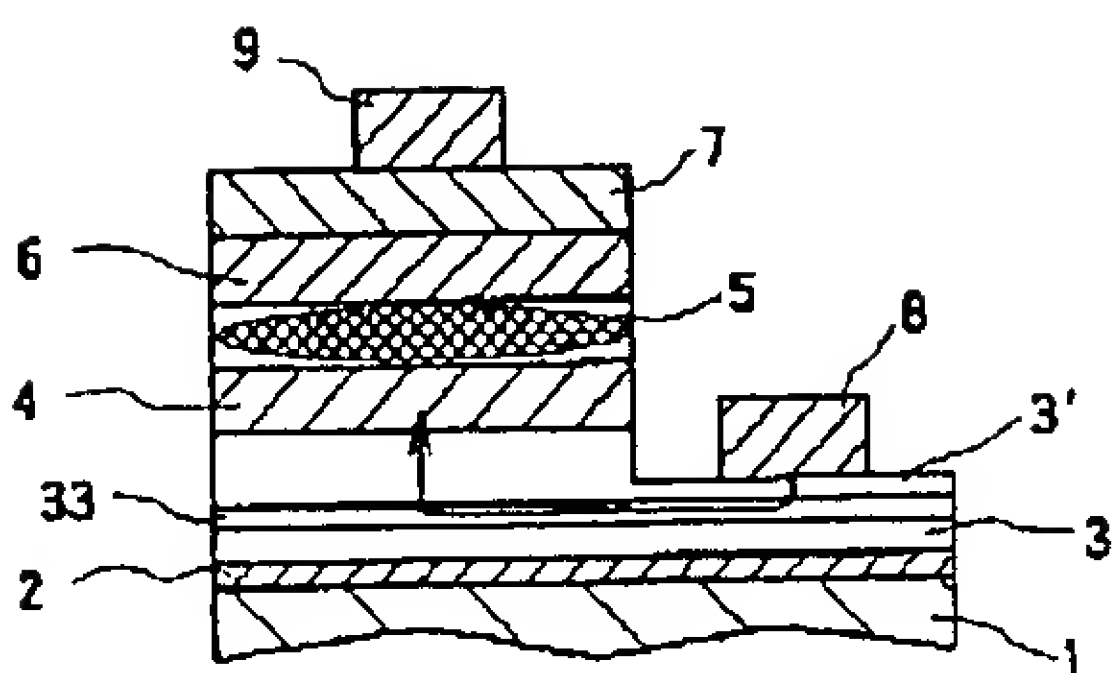


50nm InGa_{0.5}N

【図4】

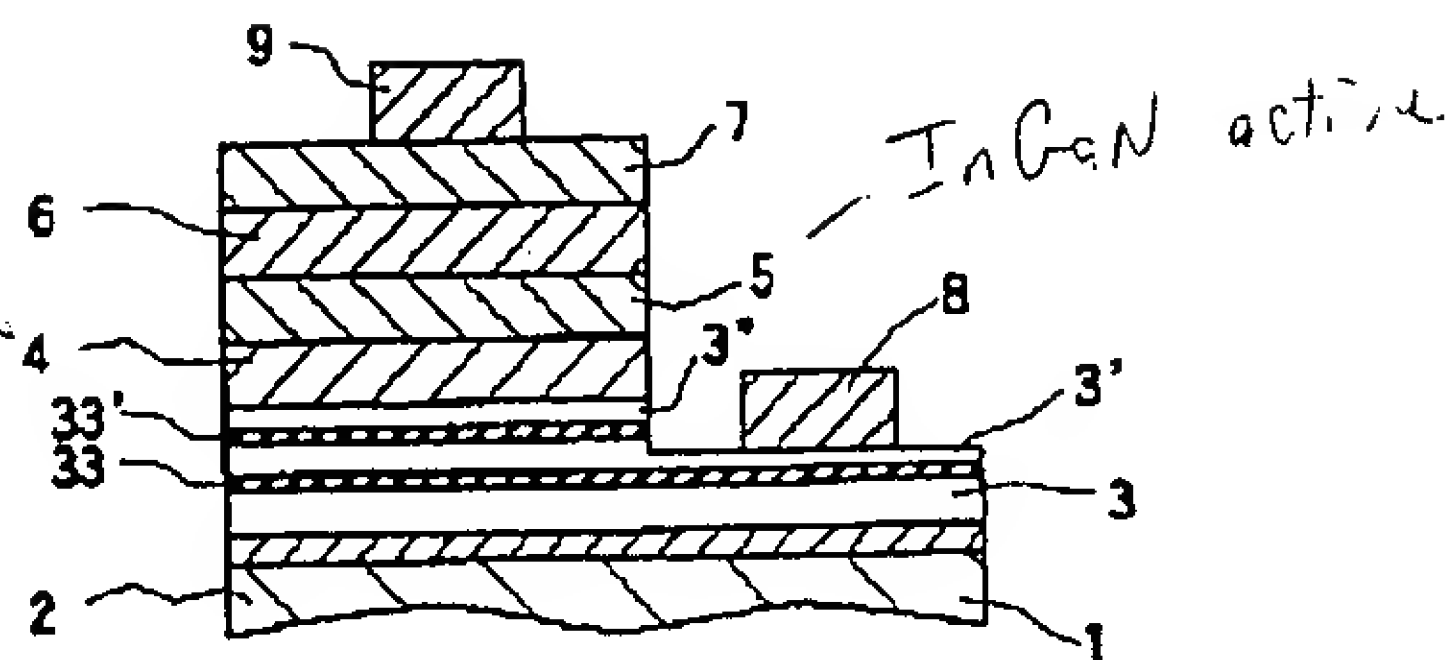


【図5】



AlGaN clad

【図6】



33 n doped > 3

[0014] 33 InGaAlN eg In_{0.5}Ga_{0.5}N
[0015] 3 AlGaIn

[0017] Zn may be multilayer

Cooling pref
1e18-1e22 10A-1μ 50A-0.3μ
1e16-1e19 1-5μ
[0010]

3
33'
GaN 1e18 1μ
In_{0.2}GaN 5e20 10nm

3' 2μ? GaN 1e18
33 10nm In_{0.2}GaN 5e20
3 1μ GaN 1e18

3 appears to be 1-3μ : not "thin"?

PATENT ABSTRACTS OF JAPAN

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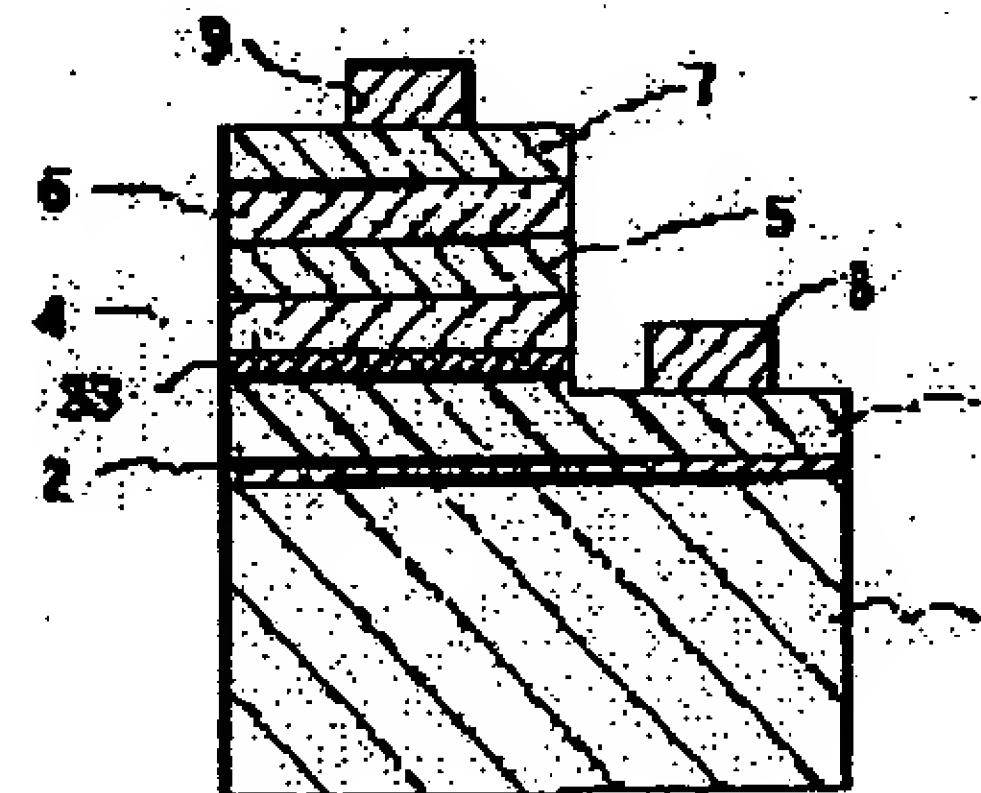
(72)Inventor : NAKAMURA SHUJI

(54) LIGHT-EMITTING ELEMENT OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR

(57)Abstract:

PURPOSE: To improve light-emitting efficiency by obtaining uniform light emission from an active layer, improving the luminosity and output of the element and further lowering V_f of the light-emitting element.

CONSTITUTION: In a gallium nitride compound semiconductor light-emitting element having a structure in which at least an n-type layer is formed between an active layer and a substrate, said n-type layer contains a first n-type layer 3 formed at the substrate side and also contains a second n-type layer 33 having electron density larger than in the first n-type layer 3 formed at the side of an active layer 5 in contact with the first n-type layer 3.



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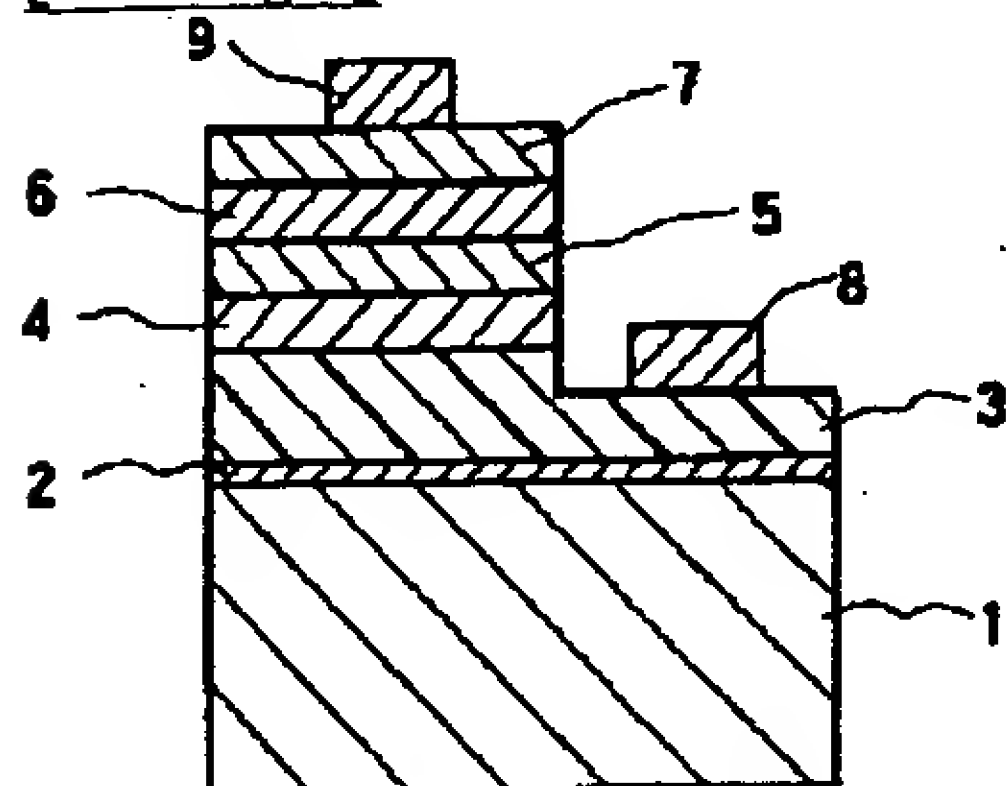
[Date of extinction of right]

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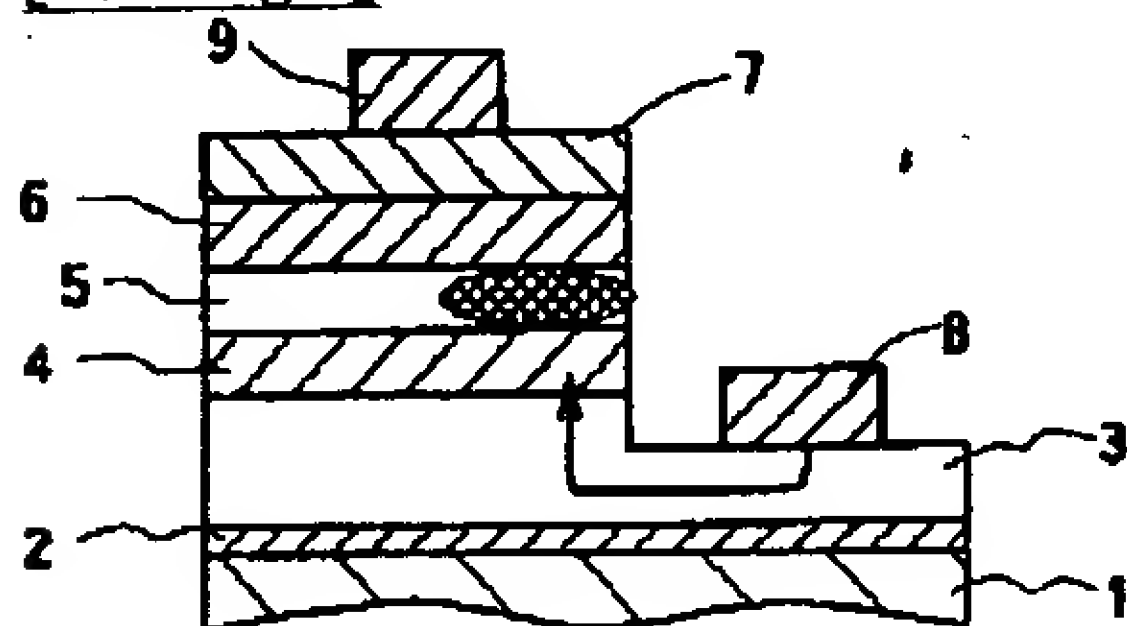
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DRAWINGS

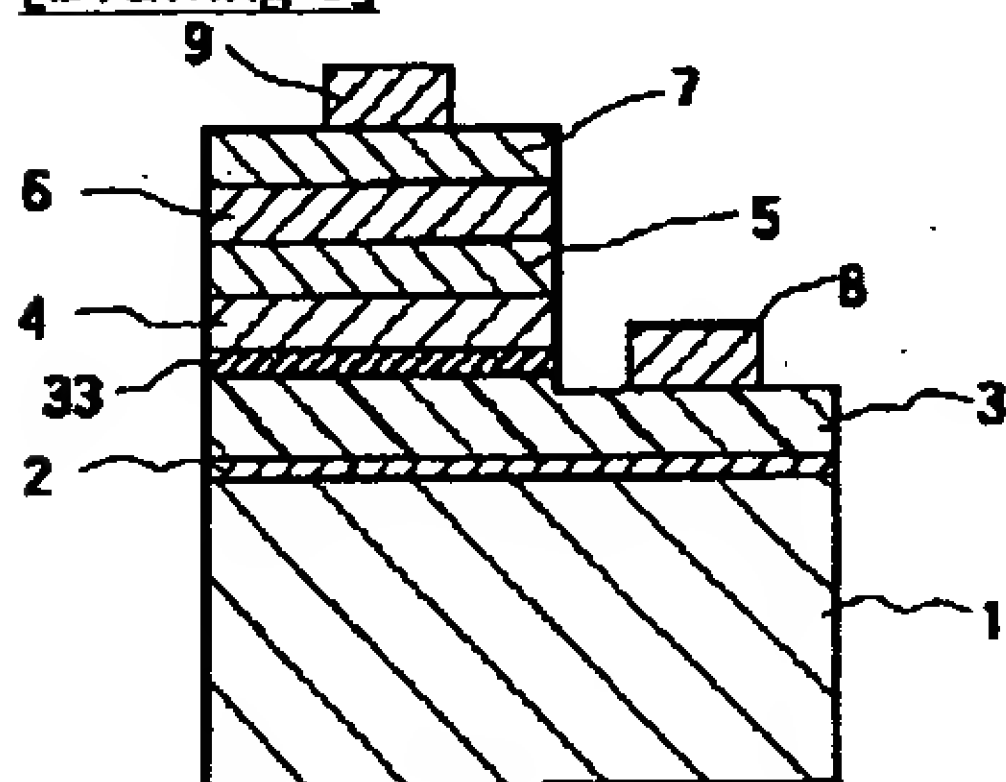
[Drawing 1]



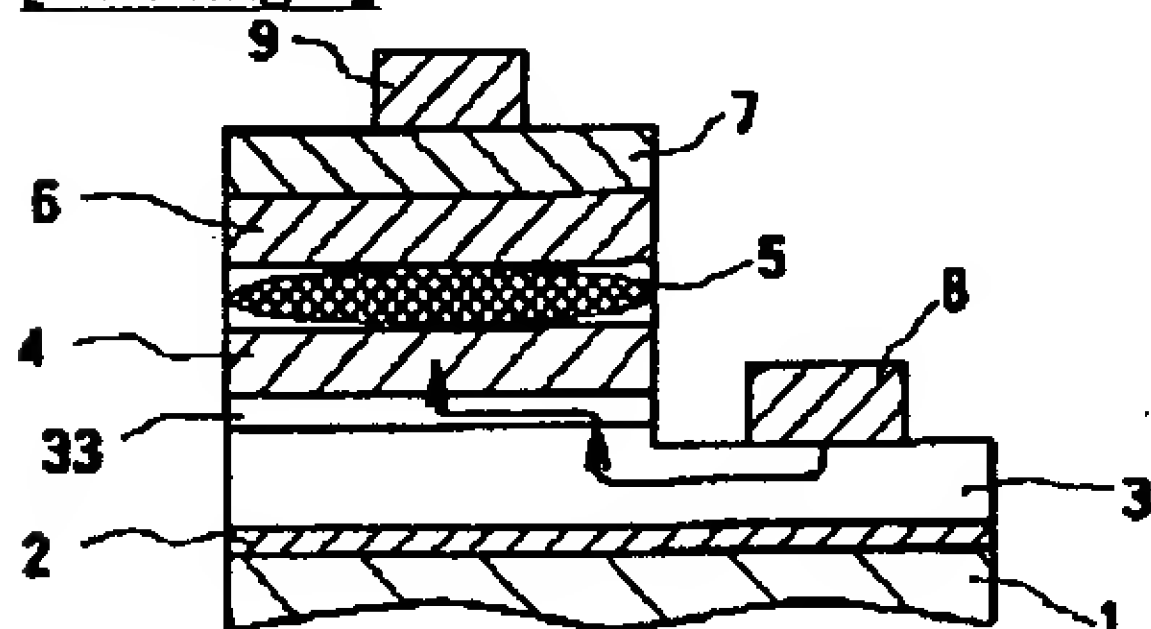
[Drawing 2]



[Drawing 3]

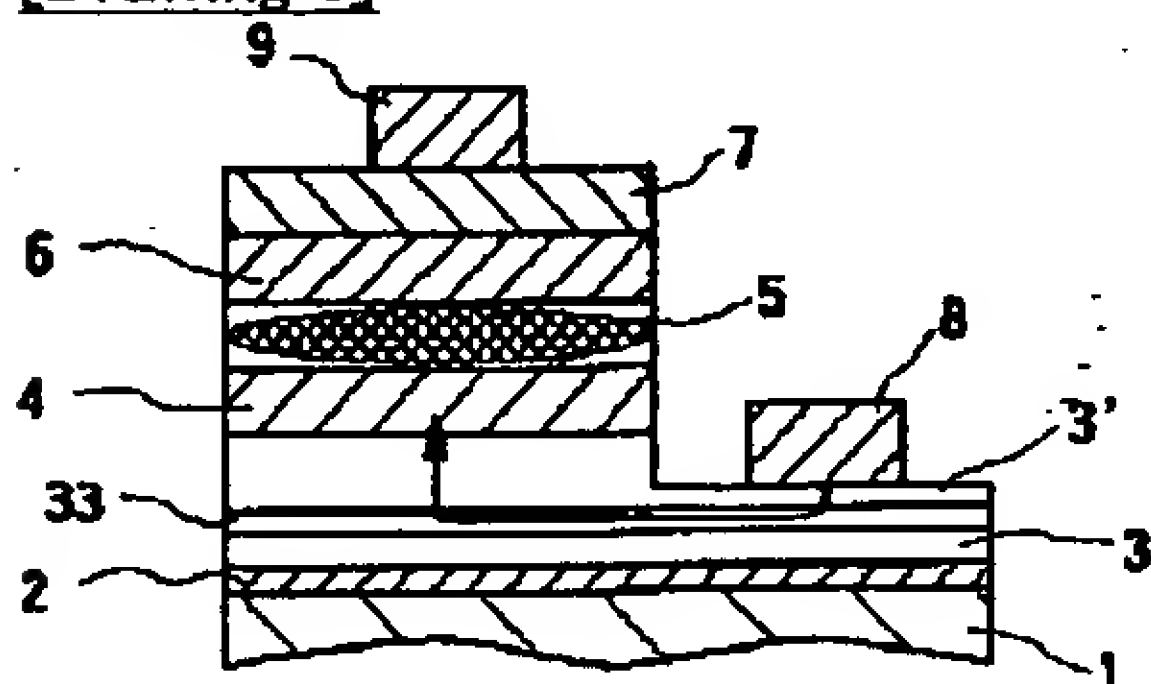


[Drawing 4]

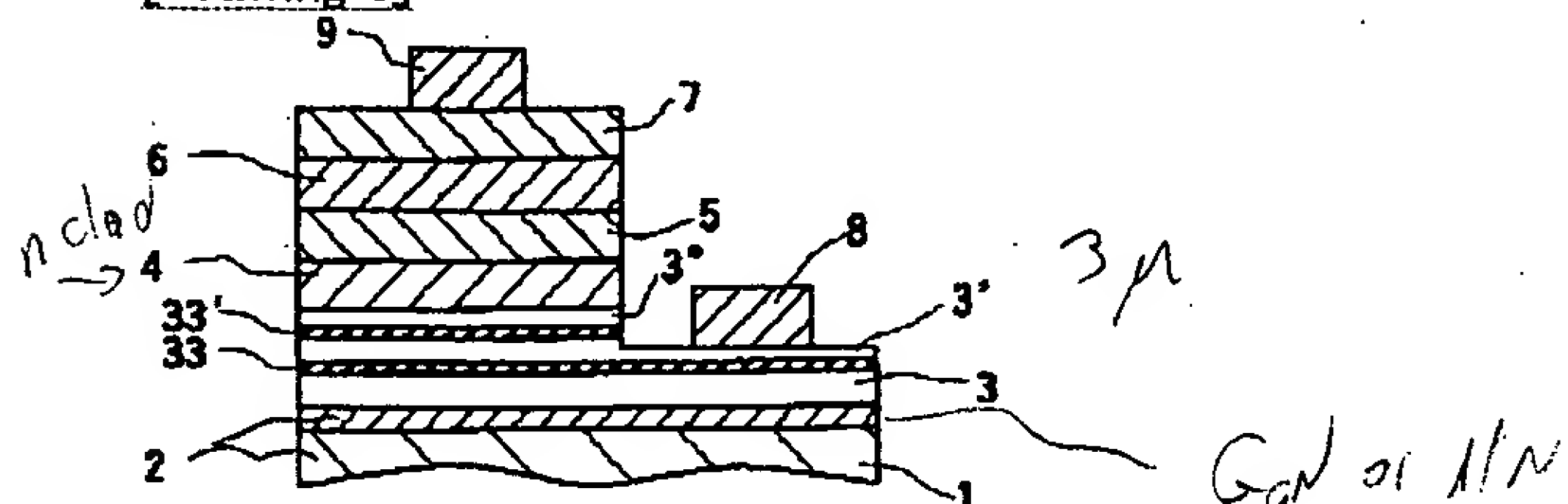


$$n_{33} > n_3$$

[Drawing 5]



[Drawing 6]



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2. *** shows the word which can not be translated.
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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The type section view showing the structure of the conventional light emitting device.

[Drawing 2] The type section view showing the luminescence state of the light emitting device of drawing 1.

[Drawing 3] The type section view showing the structure of the light emitting device of one example of this invention.

[Drawing 4] The type section view showing the luminescence state of the light emitting device of drawing 3.

[Drawing 5] The type section view showing the luminescence state of the light emitting device of other examples of this invention.

[Drawing 6] The type section view showing the structure of the light emitting device of other examples of this invention.

[Description of Notations]

1 Substrate 2 Buffer layer

4 n type clad layer 5 Barrier layer

6 p type clad layer 7 p type contact layer

8 Negative electrode 9 Positive electrode

3, 3', 3'' First n type layer (n type contact layer)

33 33' Second n type layer

[Translation done.]

second n type layer 33, and continuously grown up a GaN contact layer by 4-micrometer thickness and also similarly shown in drawing 1. The barrier layer of this light emitting device emitted light strongly between the positive electrode 9 and the negative electrode 8, as shown in drawing 2, and it was not able to obtain uniform luminescence. Moreover, in If20mA, Vf(s) were 3.6V and 1.2mW of radiant power outputs.

[0031]

[Effect of the Invention] As explained above, all the light emitting devices of this invention can realize the element which obtained uniform field luminescence from the barrier layer, and improved. Moreover, as for the light emitting device which formed second n type layer 33 between the negative electrode 8 and the substrate 1 like examples 1 and 2, Vf is falling clearly. Moreover, since an example 3 does not have a second n type layer between a substrate and a negative electrode, although there is little influence about a fall, since second n type layer is made into the multilayer, the crystal defect of Vf of a barrier layer, p type clad layer, and p type contact layer decreases, and a radiant power output's is improving. Thus, by forming second n type layer with large carrier concentration in the barrier-layer side in contact with first n type layer, the light emitting device of this invention can obtain uniform field luminescence, and can realize the element which improved.

[Translation done.]

an electron will flow through second n type layer 33 with large carrier concentration, for example as compared with drawing 4 if it is original, and an electrode 8 can be formed in the front face of second n type layer 33 with large carrier concentration, V_f of a light emitting device can be reduced. However, since an IE top is difficult for stopping etching in second n type layer 33 when an insulating substrate like sapphire is used, when distance of second n type layer 33 and a negative electrode 8 is shortened like drawing 5 and the electron poured in from the electrode 8 passes along second n type layer 33 with large carrier concentration, it becomes possible to reduce V_f .

[0019] Sapphire is used as a substrate. at least on the front face of the silicon on sapphire. Furthermore, n type layer. In the light emitting device of the structure where an electrode is formed in the front face of n type layer on which the laminating of a barrier layer and the p type layer was carried out to order, it *****ed and the p type layer and barrier layer were exposed V_f can be effectively reduced by forming second n type layer 33 between the electrode forming face of n type layer, and a substrate. Because, if it is the light emitting device of structure which grows up the gallium-nitride system compound semiconductor to be the front face of conductive substrates, such as SiC, ZnO, and Si, the electrode of n type layer can be formed in a substrate side, and the electron by the side of n layers will be perpendicularly supplied to a barrier layer. The element which has silicon on sapphire as mentioned above to it is supplied in parallel to a barrier layer. The electron-transfer distance supplied in parallel also has dozens of micrometers - hundreds of micrometers to the distance to which the electron supplied perpendicularly moves n type layer being several [at most] micrometers. Therefore, in the element to which an electron is supplied in parallel, by enlarging carrier concentration of second n type layer to which an electron is supplied in parallel, since it becomes easy to move an electron, V_f can be reduced.

[0020]

[Example]

The buffer layer 2 which becomes the front face of the substrate 1 which consists of sapphire of 2 inch phi from GaN by the [example 1] MOVPE method is grown up by 0.02-micrometer thickness. The electronic carrier concentration $5 \times 10^{17} / \text{cm}^3$ n type contact layer 3 which consists of n type GaN of $3 \times 10^{18} \text{cm}^{-3}$ which doped Si is grown up into the front face of this buffer layer 2 by 1-micrometer thickness as first n type layer.

[0021] Next, the n mold $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ layer of $1 \times 10^{20} / \text{cm}^3$ of electronic carrier concentration cm^{-3} which doped Si is grown up into the front face of n type contact layer 3 by 0.05-micrometer thickness as second n type layer.

[0022] Next, n type contact layer 3' which consists of GaN of $5 \times 10^{18} / \text{cm}^3$ of electronic carrier concentration cm^{-3} which similarly doped Si is grown up by 3-micrometer thickness.

[0023] n type clad layer which consists of n type aluminum $0.2\text{Ga}_{0.8}\text{N}$ of $1 \times 10^{18} / \text{cm}^3$ of electronic carrier concentration cm^{-3} which doped Si on the front face of n type contact layer 3' is grown up by 0.1-micrometer thickness. p type contact layer 7 which turns into 0.1 micrometers and p type clad layer 6 which consists of Mg dope aluminum $0.2\text{Ga}_{0.8}\text{N}$ from the Mg dope GaN in the barrier layer 5 which consists of Si and Zn dope n type $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ on it is grown up in order, and carries out a laminating.

[0024] the wafer obtained as mentioned above — annealing equipment — putting in — 700 degrees C — annealing — carrying out — p type clad layer 6 and p type contact layer 7 — further — low — after considering as p type [****], the mask of a predetermined configuration is formed in the front face of p type contact layer 7, etching is performed from p type contact layer side, and n type contact layer 3' is exposed

[0025] After the rest formed the negative electrode 8 in n type contact layer 3' exposed to p type contact layer 7 with the positive electrode 9 according to the conventional method, it dissociated in the shape of a chip, and it was made into the blue light emitting device of structure as shown in drawing 5. When [this] carrying out light-emitting-device luminescence, uniform field luminescence with a main luminescence wavelength of 450nm was observed from the barrier layer 5, in forward-current (I_f) 20mA, V_f was 3.3V and the radiant power output was 1.8mW.

[0026] n type contact layer 3 which becomes the front face of the [example 2] buffer layer 2 from the germanium dope GaN of electronic carrier concentration $1 \times 10^{18} / \text{cm}^3$ as first n type layer is grown up by 1-micrometer thickness, and second n type layer which becomes from germanium dope $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ of electronic carrier concentration $5 \times 10^{20} / \text{cm}^3$ at the front face is grown up by 0.01-micrometer film pressure. n type contact layer 3' which consists of germanium dope n type GaN of $1 \times 10^{18} / \text{cm}^3$ of electronic carrier concentration cm^{-3} as well as the front face of second n type layer 33 Next, 2 micrometers, Second n type layer 33' which consists of germanium dope n type $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ of $5 \times 10^{20} / \text{cm}^3$ of electronic carrier concentration cm^{-3} grows up 0.01 micrometers and the germanium dope n type GaN layer of $1 \times 10^{18} / \text{cm}^3$ of electronic carrier concentration cm^{-3} in order by 1-micrometer thickness.

[0027] The rest carried out the laminating of n type clad layer 4, a barrier layer 5, p type clad layer 6, and the p type contact layer 7 like the example 1, and made them the blue light emitting device of structure as shown in drawing 6. However, as shown in drawing 6, the etching depth from p type contact layer 7 was carried out to n type contact layer 3', and the negative electrode 8 was formed in the front face of n type contact layer 3'. And when this light emitting device was made to emit light, from the barrier layer 5, uniform field luminescence was observed like the example 1, and V_f 3.2V and the radiant power output were 2.0mW in I_f 20mA.

[0028] n type contact layer 3 which becomes the front face of the [example 3] buffer layer 2 from Si dope aluminum $0.1\text{Ga}_{0.9}\text{N}$ of electronic carrier concentration $1 \times 10^{18} / \text{cm}^3$ as first n type layer is grown up by 3-micrometer thickness. Next, second n type layer 33 which made 0.01 micrometers and Si dope aluminum $0.05\text{Ga}_{0.95}\text{N}$ of $1 \times 10^{20} / \text{cm}^3$ of electronic carrier concentration cm^{-3} the front face for Si dope $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ of $1 \times 10^{20} / \text{cm}^3$ of electronic carrier concentration cm^{-3} , and made the laminating of the 0.01 micrometers five layers at a time by turns, respectively is grown up.

[0029] Next, p type contact layer 7 which turns into 0.1 micrometers and p type clad layer 6 which consists of Mg dope aluminum $0.2\text{Ga}_{0.8}\text{N}$ from the Mg dope GaN in the barrier layer 5 which consists of Si and Zn dope n type $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ is grown up into the front face of second n type layer 33 in order, and carries out a laminating to it. That is, n type clad layer 4 of an example 1 is not grown up, and also a barrier layer 5, p type clad layer 6, and p type contact layer 7 are grown up similarly. The rest etched like the example 1 and was made into the light emitting device of structure as shown in drawing 3. Uniform field luminescence was obtained from the barrier layer 5 like the place which made this light emitting device emit light, in I_f 20mA, it was V_f 3.5V and the radiant power output was 2.2mW.

type clad layer 6 and p type contact layer 7 as single p type layer.

[0009] In the light emitting device of this invention, in order to grow up the gallium-nitride system compound semiconductor layer excellent in crystallinity, it is desirable to use sapphire for a substrate 1 preferably, to grow up GaN or AlN into a buffer layer 2, and to form by $10\text{Å} - 0.5$ micrometers thickness.

[0010] In usually forming first n type layer formed between a barrier layer 5 and a substrate 1 by 1 micrometer $- 5$ micrometers thickness as an n type contact layer 3 and forming n type clad layer 4 in the front face, it grows up by $50\text{Å} - 1$ micrometer thickness. However, it is not necessary to form specially this n type clad layer 4 as mentioned above. As a gallium-nitride system compound semiconductor, GaN and AlGaIn are desirable and set to GaN most preferably. Because, it is easy for GaN and AlGaIn to dope a non-doped or n type dopant, to serve as n type easily, and to control electronic carrier concentration by the dopant. GaN tends [furthermore] to grow for [AlGaIn] forming a crystalline good thick film by the monolayer. For example, although it is necessary to remove p type layer by etching and to expose n type contact layer 3 in order to form the electrode 8 of n type contact layer 3 when the element which carried out the laminating of n type layer and the p type layer to order by using sapphire as a substrate is realized, it is very convenient in case an actual element will be realized since there is the degree of ** of the etching depth if a thick film can be formed by the monolayer.

[0011] Next, as for a barrier layer 5, it is desirable to usually grow up by $50\text{Å} - 0.5$ micrometers thickness, and to be referred to as InGaIn. It is also easy for InGaIn to be able to change the luminescence wavelength of a light emitting device easily to purple - green by the mixed-crystal ratio of an indium using luminescence between bands, to dope n type and a p type dopant further, and to consider as an emission center. As for the mixed-crystal ratio (In/Ga) to Ga of In, it is still more desirable that it is 0.5 or less. Since more InGaIn(s) than 0.5 do not have good crystallinity, they are in the inclination it to become difficult to obtain a practical light emitting device. It is desirable that n type dopant and p type dopant are doped as a most excellent barrier layer, consider as n type, and In mixed-crystal ratio to Ga makes 0.5 or less InGaIn a barrier layer.

[0012] p type layer which grows on a barrier layer 5 also has GaN and desirable AlGaIn, p type clad layer 6 is formed by $50\text{Å} - 1$ micrometer thickness, and p contact layer 7 grows by $50\text{Å} - 5$ micrometers thickness. However, it is not necessary to make especially this p type clad layer 6 form. When a crystalline good thick film tends to grow by the monolayer, and these which form GaN and AlGaIn preferably as a gallium-nitride system compound semiconductor dope p type dopant and anneal it above 400 degrees C, they are in the inclination which serves as p type easily.

[0013]

[Function] The electron flow supplied at a barrier layer 5 is typically shown in drawing 4 from n type contact layer 3 which is first n type layer in the light emitting device of drawing 3. This shows making a barrier layer 5 emit light uniformly, when the electron supplied from n type contact layer 3 spreads [be / under / n type layer / with large electronic carrier concentration / of ** a second / 33 / passing / it] uniformly, as shown in an arrow. Thus, if first n type layer is touched and second n type layer 33 with larger electronic carrier concentration than the first n type layer is formed in a barrier-layer side, since an electron will spread uniformly in second n type layer 33, uniform field luminescence is obtained from a barrier layer 5.

[0014] As for second n type layer 33, it is good that it is desirable especially desirable to consider as $\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}\text{N}$ ($0 < x, y \leq 0$) containing an indium, and the mixed-crystal ratio (In/Ga) to Ga of In sets to 0.5 or less InGaIn. Because, compared with the crystal which the gallium-nitride system compound semiconductor containing In tends to form [whose] a layer with larger electronic carrier concentration than what is not included, and it contains In does not include, a crystal is soft and it is easy to absorb crystal defects, such as dislocation. Therefore, it is because it is possible to ease the crystal defect of the first n type layer 3 in second n type layer 33 when growing up first n type layer 3 which has not carried out grid adjustment, such as AlGaIn and GaN, on a substrate.

[0015] As for first n type layer with electronic carrier concentration smaller than second n type layer 33 with desirable [the electronic carrier concentration of second n type layer 33] and adjusting to the range of three to $1 \times 10^{22}/\text{cm}^3$ of $1 \times 10^{18}-/\text{cm}^3$, it is desirable to adjust to the range of three to $1 \times 10^{19}/\text{cm}^3$ of $1 \times 10^{16}-/\text{cm}^3$. Such electronic carrier concentration can be adjusted by doping n type dopants, such as Si, germanium, Sn, and C, in second n type layer as mentioned above. The operation which extends an electron becomes will be hard to be obtained if the electronic carrier concentration of second n type layer 33 is smaller than $1 \times 10^{18}-/\text{cm}^3$, luminescence of a uniform barrier layer is hard to be obtained, if larger than $1 \times 10^{22}-/\text{cm}^3$, crystallinity will become bad, and there is a possibility of having a bad influence on the performance of a light emitting device. Moreover, it is because luminescence of the barrier layer itself will be hard to be obtained if electronic carrier concentration is smaller than $1 \times 10^{16}-/\text{cm}^3$ also about first n type layer, and it is in the inclination for crystallinity to become bad when larger [than $1 \times 10^{19}/\text{cm}^3$] and a thick film 1 micrometers or more is formed, and there is a possibility of reducing the output of an element.

[0016] The thickness of second n type layer 33 is usually $10\text{Å} - 1$ micrometer thickness, and it is desirable to form by $50\text{Å} - 0.3$ micrometers thickness still more preferably. Since the operation which extends an electron becomes is hard to be obtained since crystallinity will become inadequate if thinner than 10Å , and luminescence of a uniform barrier layer is hard to be obtained, and it will become easy to generate a crystal defect in second n type layer if thicker than 1 micrometer, and crystallinity becomes bad, there is a possibility of worsening the performance of a light emitting device.

[0017] Furthermore, second n type layer 33 is good also as a multilayer which carried out the laminating of the gallium-nitride system compound semiconductor from which the composition ratio of In, Ga, and aluminum differs more than two-layer. It is desirable to also make still more preferably $10\text{Å} - 1$ micrometer also of thickness of each class at the time of considering as a multilayer into a $50\text{Å} - 0.3$ micrometers multilayer. While stopping the crystal defect of first n type layer in a multilayer layer by making this second n type layer 33 into a multilayer, the distortion under crystal at the time of carrying out the laminating of the gallium-nitride system compound semiconductor which has not carried out grid adjustment is eased, and since the semiconductor layer excellent in crystallinity can be grown up, the output of a light emitting device can be raised.

[0018] Next, drawing 5 is the type section view showing the structure of the light emitting device of other examples of this invention. Second n type layer 33 is formed between the negative electrodes 8 and substrates 1 which were formed in first

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention relates to the light emitting device which consists of a gallium-nitride system compound semiconductor ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 \leq a$, $0 \leq b$, $a+b \leq 1$) used for light emitting devices, such as a laser diode (LD) and light emitting diode (Light Emitting Diode).

[0002]

[Description of the Prior Art] Now, blue Light Emitting Diode with a luminous intensity of 1 cd put in practical use consists of a gallium-nitride system compound semiconductor ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 \leq a$, $0 \leq b$, $a+b \leq 1$), and has the structure shown in drawing 1. It is a structure in the double by which the laminating of the buffer layer 2 which becomes the front face of the substrate 1 which consists of sapphire from GaN, n type layer 3 which consists of GaN, n type clad layer 4 which consists of AlGaIn, the barrier layer 5 which consists of InGaIn, p type clad layer 6 which consists of AlGaIn, and the p type contact layer 7 which consists of GaN was carried out to order. This blue Light Emitting Diode indicates the highest ever performances to be forward voltage (V_f) 3.6V, the peak emission wavelength of 450nm, the luminous intensity of 1 cd, and 1.2mW of radiant power outputs by blue Light Emitting Diode in forward-current (I_f) 20mA.

[0003] In Light Emitting Diode of the aforementioned structure, although a substrate 1 has usable material other than sapphire, such as ZnO, SiC, GaAs, and Si, generally sapphire is used. As for a buffer layer 2, GaAlN besides GaN, AlN, etc. are formed. n type contact layer 3 and n type clad layer 4 are formed in a gallium-nitride system compound semiconductor by the gallium-nitride system compound semiconductor which doped n type dopants, such as Si, germanium, Sn, and C. Moreover, even if it does not divide n type contact layer 3 and n type clad layer 4 into a bilayer in this way, you may make them act as a clad layer and a contact layer as a single n type layer (it is got blocked and one of layers can be omitted). A barrier layer 5 consists of a gallium-nitride system compound semiconductor which contains an indium at least, and p type dopant and/or n type dopants, such as a non dope, and Zn, Mg, Cd, Be, are doped. After p type clad layer 6 and p type contact layer 7 dope p type dopant to a gallium-nitride system compound semiconductor, let them be p type by carrying out annealing above 400 degrees C. Moreover, you may make p type clad layer 6 and p type contact layer 7 act as a clad layer and contact layers as single p type layers (an ellipsis of one of layers is possible like n layers).

[0004]

[Problem(s) to be Solved by the Invention] In the case of the gallium-nitride system compound semiconductor, compared with III-V group compound semiconductors, such as other GaAs(es), GaP, and AlInGaP, it has the property in which current generally cannot spread easily uniformly. Then, when the Light Emitting Diode element of structure like drawing 1 is realized, there is a problem that the electron flow supplied to a barrier layer from n layers will concentrate on the low part of resistance. Drawing 2 shows luminescence of the barrier layer by concentration of current typically. As the electron supplied from the negative electrode 8 of n type contact layer 3 shows the arrow of drawing 2, this means emitting light strongly partially, as a barrier layer 5 shows the nearest distance in the half-tone-dot-meshing section by flowing so that resistance between the positive electrode 9 of p type contact layer 7 and the negative electrode 8 of n type contact layer 3 may become low. Thus, if an electron does not spread uniformly in n type contact layer 3, there is a fault that uniform luminescence is not obtained from a barrier layer 5.

[0005] Moreover, Light Emitting Diode of the above-mentioned structure reduced more than 5VV_f compared with blue Light Emitting Diode set to V_f3.6V from the gallium-nitride system compound semiconductor of the conventional MIS structure. Although this shows luminescence by p-n junction, there is room to still improve also about V_f and the further fall of V_f is desired.

[0006] Therefore, the place which this invention is made in view of such a situation, is a thing, and is made into the purpose. In the gallium-nitride system compound semiconductor light emitting device which is equipped with structure to double and equipped with the structures where n type layer was formed between the barrier layer and the substrate at least, such as structure, to a single First, luminescence more uniform than a barrier layer is obtained in the first place, it is in raising the luminous intensity of an element; and an output, V_f is reduced [second] further, and it is in raising luminous efficiency.

[0007]

[Means for Solving the Problem] By making a layer with still higher carrier concentration placed between n type layers, we found out that the above-mentioned problem was solvable. Namely, the gallium-nitride system compound semiconductor light emitting device of this invention. In a gallium-nitride system compound semiconductor light emitting device equipped with the structure where n type layer was formed between the barrier layer and the substrate at least. It is characterized by the aforementioned n type layer containing second n type layer with larger electronic carrier concentration than first n type layer by being formed in a barrier-layer side in contact with the first n type layer and first n type layer formed in the substrate side.

[0008] The structure of the light emitting device of one example of this invention is shown in drawing 3. Although fundamental structure is almost the same as the light emitting device shown in drawing 1, n type contact layer 3 which is first n type layer is touched, and second new n type layer 33 with larger electronic carrier concentration than the first n type layer 3 is formed in a barrier-layer 5 side. A substrate 1, a buffer layer 2, n type contact layer 3, n type clad layer 4, a barrier layer 5, p type clad layer 6, and p type contact layer 7 grade can be formed by the gallium-nitride system compound

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CLAIMS

[Claim(s)]

[Claim 1] The gallium-nitride system compound semiconductor light emitting device equipped with the structure where n type layer was formed between the barrier layer and the substrate at least characterized by providing the following. The aforementioned n type layer is first n type layer formed in the substrate side. Second n type layer with electronic carrier concentration it is formed in a barrier-layer side in contact with the first n type layer, and larger than first n type layer.

[Claim 2] The gallium-nitride system compound semiconductor light emitting device according to claim 1 characterized by the bird clapper from the gallium-nitride system compound semiconductor ($\text{In}_X\text{Al}_Y\text{Ga}_{1-X-Y}\text{N}$, $0 < X$, $0 \leq Y$, $X+Y \leq 1$) in which n type layer of the above second contains an indium at least.

[Claim 3] n type layer of the above second is a gallium-nitride system compound semiconductor light emitting device according to claim 1 or 2 to which the gallium-nitride system compound semiconductor layer from which composition differs mutually is characterized by the bird clapper from the multilayer by which the laminating was carried out more than two-layer.

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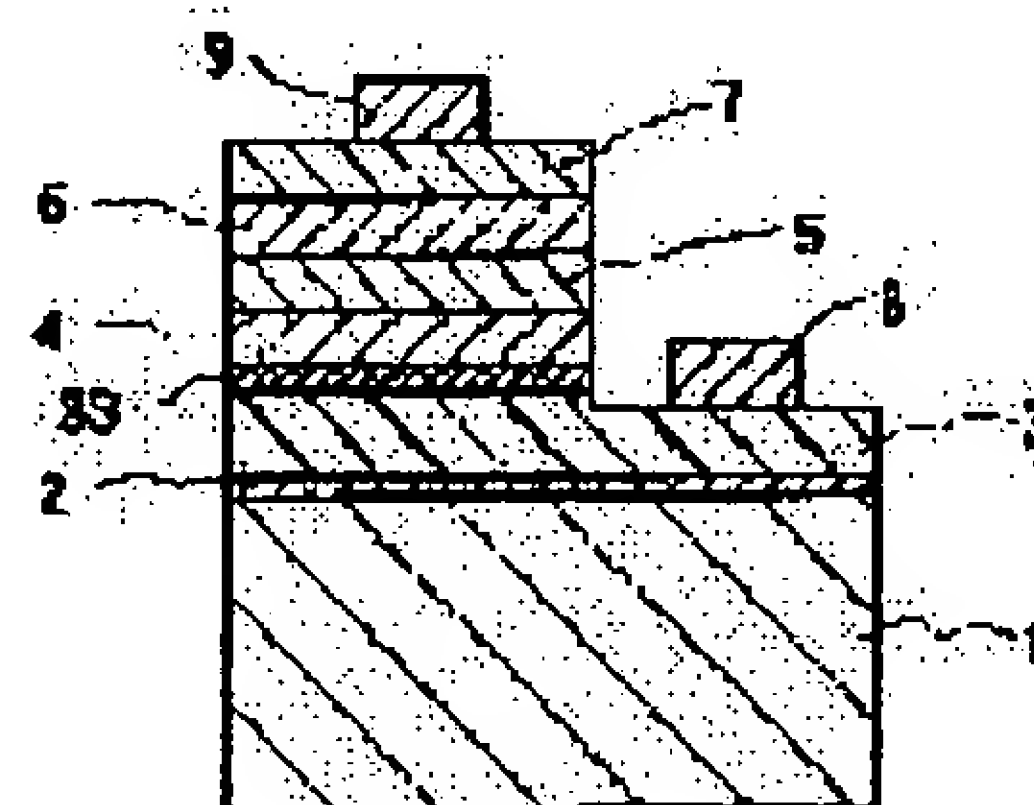
(72)Inventor : NAKAMURA SHUJI

(54) LIGHT-EMITTING ELEMENT OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR

(57)Abstract:

PURPOSE: To improve light-emitting efficiency by obtaining uniform light emission from an active layer, improving the luminosity and output of the element and further lowering V_f of the light-emitting element.

CONSTITUTION: In a gallium nitride compound semiconductor light-emitting element having a structure in which at least an n-type layer is formed between an active layer and a substrate, said n-type layer contains a first n-type layer 3 formed at the substrate side and also contains a second n-type layer 33 having electron density larger than in the first n-type layer 3 formed at the side of an active layer 5 in contact with the first n-type layer 3.



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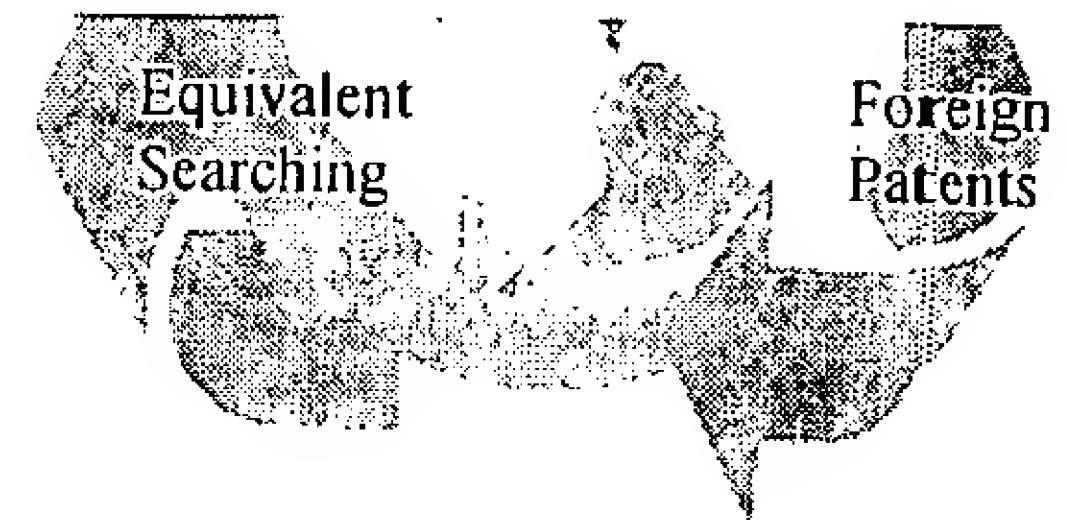
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GALIUM NITRIDE TYPE OF COMPOUND SEMICONDUCTOR LIGHT

EMITTING ELEMENT

(Chikka gariumu kei ka kago butsu hadotai hatsu ko soshi)

Shuichi Nakamura et al

UNITED STATES PATENT AND TRADEMARK OFFICE

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Foreign Language Title : Chikka garium kei kago
butsu handotai hatsu ko
soshi

English Title : Gallium nitride type of
compound semiconductor
light emitting element

[Title of Invention] Gallium nitride type of compound
semiconductor light emitting element

[Summary]

[Purpose] To obtain a uniform light emitting from the
active layer and to improve the brightness of the element
and to improve the output. Also, to reduce further the Vf
in the light emitting element, the light emitting
efficiency can be improved.

[Constitution] In a Gallium nitride type of compound
semiconductor light emitting element that is provided with
a structure that consists of at least one n- type layer
formed between the active layer and the substrate, the
aforementioned n type layer consists of the 1st n type layer
3 that is formed at the substrate side and the 2nd n type
layer 33 that is formed at the active layer 5 side that is
touching that 1st n type layer 3. It has higher
concentration of electron carriers than the 1st n type layer
3.

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[Scope of Patent Claims]

¹ Numbers in the margin indicate pagination in the foreign text.

[Claim 1] In a Gallium nitride type of compound semiconductor light emitting element that is provided with a structure that consists of at least one n- type layer formed between the active layer and the substrate, the aforementioned n type layer consists of the 1st n type layer that is formed at the substrate side and the 2nd n type layer that is formed at the active layer side that is touching that 1st n type layer. It has higher concentration of electron carriers than the 1st n type layer.

[Claim 2] The aforementioned 2nd n type layer in the nitride gallium type compound semiconductor light emitting element stated in Claim 1 is characterized as being made from gallium nitride type compound semiconductor ($\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}\text{N}$, $0 < X$, $0 < Y$, $X+Y < 1$) containing at least one of this, Indium.

[Claim 3] The aforementioned 2nd n type layer in the nitride gallium type compound semiconductor light emitting element stated in Claim 1 or Claim 2 is characterized as being made from gallium nitride type compound semiconductor consisting of lamination of above 2 layers of different composition.

[Detailed explanation of the invention]

[0001]

[Industrial field of use] The invention pertains to a light emitting element made from gallium nitride type compound

semiconductor ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 < a$, $0 < b$, $a+b < 1$) used in the light emitting element such as light emitting diode (LED) and laser diode (LD).

[0002]

[Prior Art] At present, the blue color LED of light emitting light of lcd is made of gallium nitride type compound semiconductor ($\text{In}_a\text{Al}_b\text{Ga}_{1-a-b}\text{N}$, $0 < a$, $0 < b$, $a+b < 1$), its structure is shown in figure 1. The double hetero structure is laminated respectively with the following layers on the top surface of the substrate 1 made of sapphire, that is, the buffer layer 2 made from GaN, the n type layer 3 made from GaN, the n type clad layer 4 made from AlGaIn, the active layer 5 made from InGaIn, the p type clad layer 6 made from AlGaIn and the p type contact layer 7 made from GaN. This blue color LED has sequence direction current flow (I_f) of 20 mA, the sequence direction voltage (V_f) is 3.6 V, the peak light emitting wavelength is 450 nm, the degree of light emitting is lcd, the light generating output is 1.2 mW, the blue color LED shows excess high performance.

[0003] In the LED of the aforementioned structure, the materials given as follows can be used instead of the sapphire for the substrate 1, for example, ZnO, SiC, GaAs, Si. However, in general, sapphire is used. The buffer layer

2 is formed with GaAlN, AlN in addition to GaN. The n type contact layer 3, the n type clad layer 4 are formed with the gallium nitride type compound semiconductor doped with the n type do-pant such as Si, Ge, Sn, C onto the gallium nitride type compound semiconductor. Also, the n type contact layer 3, the n type clad layer 4 acts as the clad layer and the contact layer and as the single n type layer not divided into two layer (then, either layer can be omitted). The active layer 5 is made from the gallium nitride type compound semiconductor that consists of indium, it is doped with the p type dopant and/or the n type of dopant such as Zn, Mg, Cd, Be or it is non-doped. After the p type clad layer 6 and the p type contact layer 7 are doped with the p type dopant on the gallium nitride type compound semiconductor, it is annealed above 400 degree C and becomes the p type. Also, the p type clad layer 6 and the p type contact layer 7 are acted as the single p type layer, the clad layer and the contact layer (any of these layers can be omitted similar to the n layer).

[0004]

[The problems resolved by the invention] The gallium nitride type compound semiconductor has non-uniform current flow as compared to the Group III - V compound

semiconductor such as GaAs, GaP, AlInGaP. When the LED element having the structure shown in Figure 1 is obtained, the flow of the electron supplied to the active layer from the n layer all concentrates in the location with low resistance which is a problem. Figure 2 show a typical model of the light emitting active layer due to the concentration of the current. The electron is supplied from the negative electrode 8 of the n type contact layer 3 as shown in the arrow of figure 2. The resistance between the positive electrode 9 of the p type contact layer 7 and the negative electrode 8 of the n type contact layer 3 is reduced. By flowing the current at a closer distance, the active layer 5 emits strong light partially shown with the net hanging part. Thus, the electrons are uniform at the n type contact layer 3 but the drawback is that uniform light emitting cannot be obtained from the active layer 5.

[0005] Also, the LED of the above structure has V_f 3.6 V as compared to the blue color LED made from the gallium nitride type compound semiconductor of the conventional MIS structure which has V_f of above 5V. The light is emitted by the p - n bond so there is a need for the improvement of the V_f . In addition, the reduction of V_f is desired.

[0006] Therefore, the purpose of the invention is to focus on the above problems and offer a gallium nitride type

compound semiconductor light emitting element that is provided with a structure where the n type layer is formed between the active layer and the substrate such as the double hetero and the single hetero. Uniform light emitting can be obtained from the active layer. First, the brightness of the element and the output are improved. Second, the V_f is reduced and the light emitting efficiency is improved.

[0007]

[Means for resolving the problems] The purpose of the invention is to resolve the above problems by having a layer consisting of high concentration of electron carriers in the n type layer. That is, in a Gallium nitride type of compound semiconductor light emitting element that is provided with a structure that consists of at least one n-type layer formed between the active layer and the substrate, the aforementioned n type layer consists of the 1st n type layer that is formed at the substrate side and the 2nd n type layer that is formed at the active layer side that is touching that 1st n type layer. It has higher concentration of electron carriers than the 1st n type layer.

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[0008] The structure of the light emitting element of one implementation example of the invention is shown in figure 3. The basic structure is the same as the light emitting element shown in figure 1. It is placed close to the n type contact layer 3 which is the 1st n type layer. The 2nd n type layer 33 is formed with large electron carrier concentration than the 1st n type layer 3, this is formed at the active layer 5 side. The gallium nitride type compound semiconductor is formed with a substrate 1, a buffer layer 2, the n type clad layer 4, an active layer 5, a p type clad layer 6, the p type contact layer 7. These are formed as a single layer, the n type clad layer 4 and the n type contact layer 3. Also, the p type clad layer 6 and the p type contact layer 7 can be the single layer p type.

[0009] In the light emitting element of the invention, it is preferred that sapphire is used for the substrate 1, the gallium nitride type compound semiconductor layer is grown having excellent crystallinity. GaN or AlN are grown on the buffer layer 2 and it is grown into a thickness of 10 angstroms - 0.5 μm .

[0010] The 1st n type layer formed between the active layer 5 and the substrate 1 is formed into a standard thickness of 1 μm - 5 μm as the n type contact layer 3. When the n type clad layer 4 is formed on the top surface, the

thickness is 50 angstroms to 1 μm . Therefore, as mentioned above, it is preferred that this n type clad layer 4 is formed. It is preferred that GaN, AlGaN is used in the gallium nitride type compound semiconductor. The most preferred is GaN. GaN and AlGaN become the n type doped with the n type dopant or it is non-doped. The electron carrier concentration can be controlled easily by the dopant. In addition, GaN grow easily forming a thick single layer crystal from the AlGaN. For example, when the n type layer and the p type layer are laminated in this order on the sapphire substrate, the light emitting element is obtained. Since the electrode 8 is provided in the n type contact layer 3, the p type layer is removed by etching and the n type contact layer 3 must be exposed and a thickness of a single layer is formed. Since the etching depth is not fixed, a real element can be realized which is highly desirable.

[0011] Next, the active layer 5 is grown with a standard thickness of 50 angstroms - 0.5 μm , InGaN film is obtained. The light emitting wavelength of the light emitting element using the light emitted between the band by the indium crystals of InGaN mixture can be changed easily to red - green color. In addition, the n type and p type dopant are doped and it is used easily as the core for emitting the

light. In addition, it is preferred that the crystals mixture ratio (In/Ga) for the In in Ga is below 0.5. When the InGaN is more than 0.5, the crystallinity is poor and it tends to be difficult to obtain a light emitting element practically. An example of an excellent layer is the n type doped with the n type dopant and the p type dopant. The In crystal mixture ratio in Ga is below 0.5, the InGaN layer becomes the preferred active layer.

[0012] It is preferred that the P type layer GaN and AlGaN are grown on top of the active layer 5. The p type clad layer 6 is formed at a thickness of 50 angstroms - 1 μm . The p contact layer 7 is formed at a thickness of 50 angstroms - 5 μm . That is, this p type clad layer 6 is not formed in any special form. It is preferred that GaN, AlGaN are preferred to be formed as the gallium nitride type compound semiconductor. The film thickness can be grown easily in a single layer with good crystallinity. Also, the p type dopant is doped and it is annealed easily above 400 degree, this tends to become the p type.

[0013]

[Action] A typical model of the current flowing in the electrons are supplied to the active layer 5 from the n type contact layer 3 which is the 1st n type layer in the light emitting element of figure 3. Active layer 5 emits

uniform light by increasing the electrons uniformly via the 2nd n type layer 33 of large electron carrier concentration as shown in the direction of the arrow. This touches the 1st n type layer. When the 2nd n type layer 33 formed at the active layer side has large electron carrier concentration than the 1st n type layer at the 1st n type layer, since the electrons increased uniformly in the middle of the 2nd n type layer 33, a uniform light emitting surface is obtained from the active layer 5.

[0014] It is preferred that the 2nd n type layer 33 becomes the $\text{In}_x\text{Al}_y\text{Ga}_{1-x-y}\text{N}$ ($0 < x, y < 1$) containing Indium. In particular, it is preferred that the crystals mixture ratio (In/Ga) of the In in Ga is below 0.5, this InGa_{0.5}N mixture is preferred. In addition, the gallium nitride type compound semiconductor containing In can form easily the layer with a large concentration of electron carrier than the one not containing it. Also, the crystal containing the In has soft crystal than the one that do not contain any. The crystal flaw is absorbed easily like the rotation position. Therefore, when the 1st n type layer that do not contain the lattice of AlGa_{0.5}N and GaN grows the 1st n type layer 3 on the substrate, the crystal flow of that 1st n type layer 3 can be pacified with the 2nd n type layer 33.

[0015] The concentration of the electron carriers in the 2nd n type layer 33 is preferred to be adjusted in the range of $1 \times 10^{18}/\text{cm}^3 - 1 \times 10^{22} / \text{cm}^3$. Also, it is preferred that the concentration of the electron carriers in the 1st n type layer that is smaller than that concentration in the 2nd n type layer 33 is preferred to be adjusted to the range of $1 \times 10^{16}/\text{cm}^3 - 1 \times 10^{19} / \text{cm}^3$. Also, it is preferred that the electron carrier concentration can be adjusted by doping the n type dopant such as Si, Ge, Sn and C on the 2nd n type layer. If the electron carrier concentration of the 2nd n type layer 33 is smaller than $1 \times 10^{18}/\text{cm}^3$, it is difficult to obtain the action of widening the electrons, a uniform active layer for emitting light is difficult to obtain. When it is larger than $1 \times 10^{22} / \text{cm}^3$, poor crystallinity is obtained. If the electron carrier concentration of the 1st n type layer is smaller than $1 \times 10^{16}/\text{cm}^3$, it is difficult to emit light from the active layer itself. Also, if the electron carrier concentration is smaller than $1 \times 10^{19}/\text{cm}^3$ and the film thickness is above 1 μm , the crystallinity tends to become poor, the output of the element is reduced.

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[0016] The thickness of the 2nd n type layer 33 is usually at a thickness of 10 angstroms to 1 μm . In addition, it is preferred to be formed at a thickness of 50 angstroms - 0.3

μm . If it is less than 10 angstroms, the crystallinity is insufficient, the action to enlarge the electrons is difficult to obtain and it is difficult to obtain light emitting from the uniform active layer. Also, since the crystallinity is poor as the thickness is more than 1 μm , the crystal flaw is generated easily in the 2nd n type layer, the function of the light emitting element becomes poor.

[0017] In addition, the 2nd n type layer 33 is preferred to be multilayered of above 2 layers of the gallium nitride type compound semiconductor with different composition ratio of In, Ga and Al. When this is a multilayered structure, it is preferred that the thickness of each layer is 10 angstroms - 1 μm . In addition, it is preferred that the thickness of the multilayered structure is at 50 angstroms - 0.3 μm . By multilayering this 2nd n type layer 33, the crystal flaw of the 1st n type layer can be suppressed with this multilayer film. Also, the torsion in the crystal can be buffered by the laminating of the gallium nitride type compound semiconductor. An excellent semiconductor layer having good crystallinity can be grown and the output of the light emitting element can be improved.

[0018] Next, figure 5 is the typical cross section showing the structure of the light generating element of another example of the invention. The 2nd n type layer 33 is formed between the substrate 1 and the negative electrode 8 formed on the 1st n type layer 3. This shows the distance of the 2nd n type layer 33 and the negative electrode 8 is close. In this case, the electrode 8 can be formed on the surface of the 2nd n type layer 33 with large carrier concentration. For example, as compared to figure 4, since there are a large concentration of electron carriers flowing through the 2nd n type layer 33, Vf of the light emitting element can be reduced. In addition, when an insulated substrate is used such as sapphire, since the etching is difficult in terms of production technique with the stopping by the 2nd n type layer 33, the distance of the 2nd n type layer 33 and the negative electrode 8 shown in figure 5 is reduced. By having a large electron carrier concentration entering from the electrode 8 via the 2nd n type layer 33, Vf can be reduced.

[0019] In addition, the substrate is made of sapphire, the n type layer, an active layer and a p type layer are laminated in this order on the surface of that sapphire substrate. In this light emitting element where an electrode is formed on the surface of the n type layer that

is etched and exposed with that p type layer and the active layer, the 2nd n type layer 33 is formed between the n type layer electrode formation surface and the substrate, the V_f can be reduced effectively. In addition, the light emitting element of the structure formed with the gallium nitride type compound semiconductor is grown on the surface of the conductive substrate such as SiC, ZnO and Si. The n type layer electrode is formed on the substrate side. The electrons at the n layer side is supplied to perpendicular to the active layer side. The electrons having the sapphire substrate as discussed above are supplied parallel to the active layer. The electrons that are supplied perpendicularly have a moving distance in the n type layer of several μm and the moving distance of the electron supplied in the parallel direction of several μm to several hundred μm . Therefore, in the element where the electrons are supplied in the parallel direction, the carrier concentration of the 2nd n type layer supplying the electrons in the parallel direction is increased. The electrons move easily and the V_f is reduced.

[0020]

[Implementation example]

[Implementation example 1] According to the MOVPE method, the buffer layer 2 made from GaN is grown into a thickness of $0.02\text{ }\mu\text{m}$ on the top surface of the substrate 1 made from sapphire of 2 inch diameter. The 1st n type layer is formed on the top surface of this buffer layer 2. The n type contact layer 3 made with the n type GaN of $1\text{ }\mu\text{m}$ in thickness and of electron carrier concentration of $5 \times 10^{18}/\text{cm}^3$ that is doped with Si is grown as the 1st n type layer on the surface of this buffer layer 2.

[0021] Next, the n type $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ of $0.05\text{ }\mu\text{m}$ in thickness and of electron carrier concentration of $1 \times 10^{20}/\text{cm}^3$ that is doped with Si is grown as the 2nd n type layer on the surface of the n type contact layer 3.

[0022] Next, the n type contact layer 3' made from GaN of $3\text{ }\mu\text{m}$ in thickness and of electron carrier concentration of $5 \times 10^{18}/\text{cm}^3$ that is doped with Si is grown.

[0023] The n type clad layer made from the n type $\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}$ of $0.1\text{ }\mu\text{m}$ in thickness and of electron carrier concentration of $1 \times 10^{18}/\text{cm}^3$ that is doped with Si is grown on the surface of the n type contact layer 3'. An active layer made from Si and Zn dope n type $\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$ of $0.1\text{ }\mu\text{m}$ in thickness, the p type clad layer 6 made from Mg dope $\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}$ and the p type contact layer 7 made from Mg

dope GaN are grown and laminated in this order on the top surface.

[0024] The wafer obtained according to the above method is introduced into annealing machine and it is annealed at 700 degree C. After the p type clad layer 6 and the p type contact layer 7 are made into a low resistance p type. The mask in a certain form is formed on the surface of the p type contact layer 7. Etching is performed from the p type contact layer side and the n type contact layer 3' is exposed.

[0025] Then, according to a normal method, after the positive electrode 9 is formed on the p type contact layer 7 and the negative electrode 8 is formed on the exposed n type contact layer 3', it is separated into a chip shape. This becomes the blue color light emitting element of the structure shown in figure 5. With this light emitting element, a uniform light emitting surface is observed, the main light emitting wavelength of 450 nm is from the active layer 5. In the current flow direction (I_f) is 20 mA, the V_f is 3.3V, the light emitting output is 1.8 mW.

[0026] [Implementation example 2] An n type contact layer 3 is grown into a thickness of 1 μm , this is made up of Ge doped GaN 10.1 of electron carrier concentration of $1 \times 10^{18}/\text{cm}^3$, this is formed on the top surface of the buffer

layer 2. Next, the 2nd n type layer made from Ge dope In 0.2 Ga0.8N of 0.01 μm of electron carrier concentration of $5 \times 10^{20}/\text{cm}^3$ is formed on this top surface. Next, the n type contact layer 3' made from Ge dope n type GaN of 2 μm of electron carrier concentration of $1 \times 10^{18}/\text{cm}^3$, the 2nd n type layer 33' made from Ge dope n type In0.2Ga0.8N of 0.01 μm of electron carrier concentration of $5 \times 10^{20}/\text{cm}^3$, Ge dope n type GaN layer of 1 μm of electron carrier concentration of $1 \times 10^{18}/\text{cm}^3$ are formed in this order on the top surface of the 2nd n type layer 33.

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[0027] The n-type clad layer 4, the active layer 5, the p type clad layer 6, the p type contact layer 7 are laminated similar to that implementation example 1. This becomes the blue color light emitting element having the structure shown in figure 6. Therefore, as shown in figure 6, the depth of the etching is from the p type contact layer 7 to the n type contact layer 3'. The negative electrode 8 is formed on the surface of the n type contact layer 3'. Then, when this light emitting element emits light, a uniform surface light emitting is measured from the active

layer 5 similar to implementation example 1. The emitting output is 2.0 mW with V_f of 3.2 V and I_f of 20 mA.

[0028] [Implementation example 3] An n type contact 3 is grown into a thickness of 3 μm , this is made up of Si doped A 10.1 Ga0.9N of electron carrier concentration of $1 \times 10^{18}/\text{cm}^3$, this is formed on the top surface of the buffer layer 2. Next, 5 layers each of the following are laminated on this top surface, Si dope In 0.2 Ga0.8N of 0.01 μm of electron carrier concentration of $1 \times 10^{20}/\text{cm}^3$ and Si dope A 10.05 Ga0.95N of 0.01 μm of electron carrier concentration of $1 \times 10^{20}/\text{cm}^3$. The 2nd n type layer 33 is grown.

[0029] Next, the following are formed and laminated in this order on the top surface of the 2nd n type layer 33, 0.1 μm of the active layer 5 made from Si and Zn dope n type In 0.1 Ga0.9N, the p type clad layer 6 made from the Mg dope A 10.2 GA0.8N and the p type contact layer 7 made from Mg dope GaN. Next, the active layer 5, the p type clad layer 6, the p type contact layer 7 are formed similarly without forming the n type clad layer 4 of implementation example 1. Then, the etching is performed similar to implementation example 1. The light emitting element having the structure shown in figure 3 is obtained. Uniform surface light emitting is obtained from the active layer 5 similar to

when this light emitting element emits light. When I_f is 20 mA, V_f is 3.5 V, the light emitting output is 2.2 mW.

[0030] [Comparison example] The 2nd n type layer 33 in implementation example 1 is not formed here but the rest of the example is carried out similarly. A GaN contact layer is formed continuously to 4 μm thickness. The structure of this light emitting element is shown in figure 1. The active layer of this light emitting element has strong light emission between the positive electrode 9 and negative electrode 8 shown in figure 2. A uniform light emission cannot be obtained. Also, when I_f is 20 mA, V_f is 3.6 V, the light emitting output is 1.2 mW.

[0031]

[Effect of invention] According to the invention as described above, this light emitting element can provide improved light emitting output, a uniform light emitting surface can be obtained from the whole active layer. Also, according to implementation examples 1 and 2, the 2nd n type layer 33 is formed between the negative electrode 8 and the substrate 1, it is clear the V_f is reduced. Also, in implementation example 3, since the 2nd n type layer is not formed between the substrate and the negative electrode, the reduction of V_f is not affected. Also, since the 2nd n type layer is multilayered, there are less flaws in the

crystal in the active layer, the p type clad layer and the p type contact layer. The light emitting element of the invention can be formed at the active layer side where the 2nd n type layer is bonded to the 1st n type layer. Uniform light emitting surface can be obtained. Thus, the element with improved light emitting output can realized.

[Brief explanation of the diagrams]

[Figure 1] This is a typical cross section showing the structure of the conventional light emitting element.

[Figure 2] This is a typical cross section showing the light emitting state of the light emitting element of figure 1.

[Figure 3] This is a typical cross section showing the structure of the light emitting element of one implementation example of the invention.

[Figure 4]] This is a typical cross section showing the light emitting state of the light emitting element of figure 3.

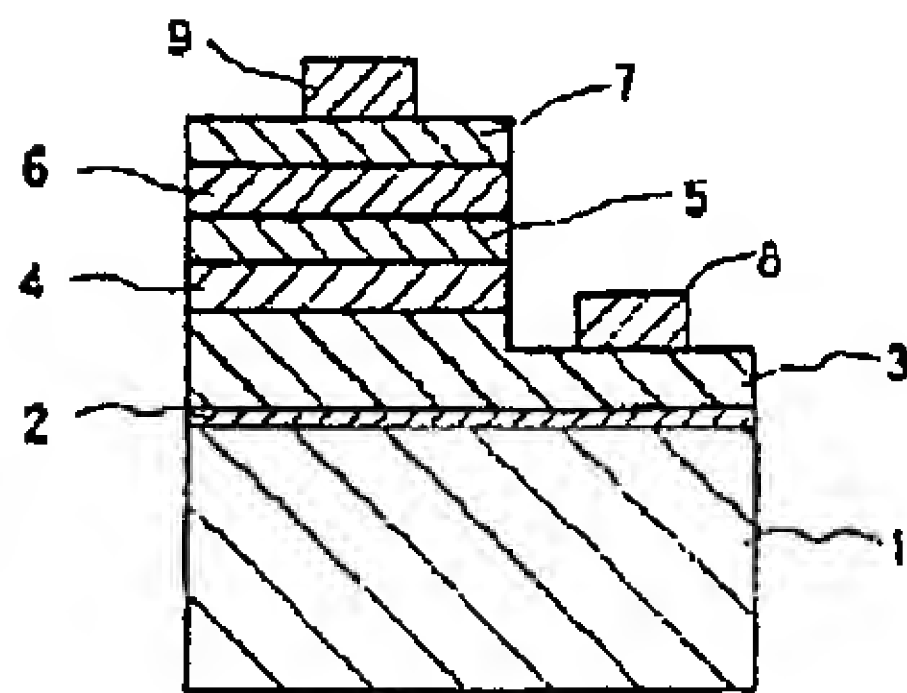
[Figure 5] This is a typical cross section showing the light emitting state of the light emitting element of another implementation example of the invention.

[Figure 6] This is a typical cross section showing the light emitting state of the light emitting element of another implementation example of the invention.

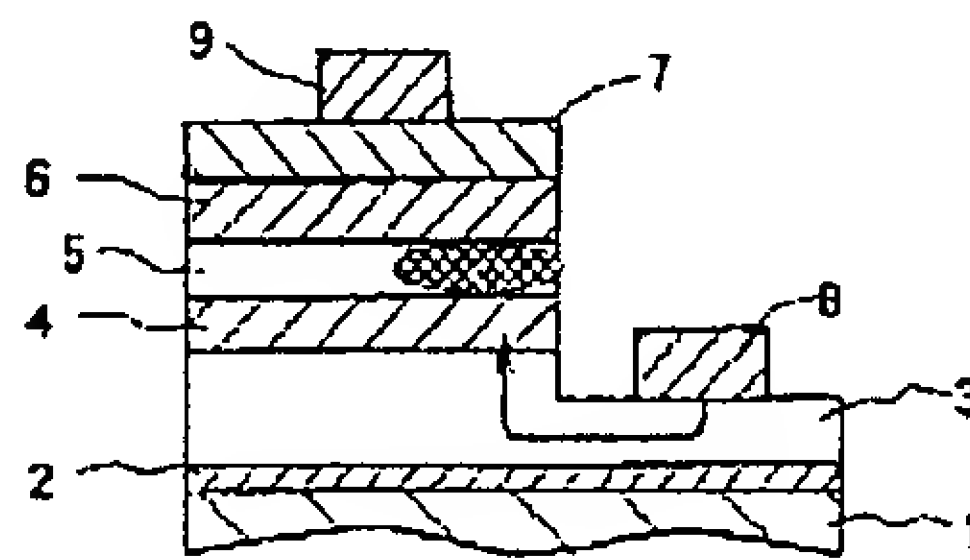
[Description of the symbols]

1 - the substrate, 2 - the buffer layer, 4 - the n type clad layer, 5 - the active layer, 6 - the p type clad layer, 7 - the p type contact layer, 8 - the negative electrode, 9 - the positive electrode, 3, 3', 3'' - The 1st n type layer (n type contact layer), 33, 33' - The 2nd n type layer

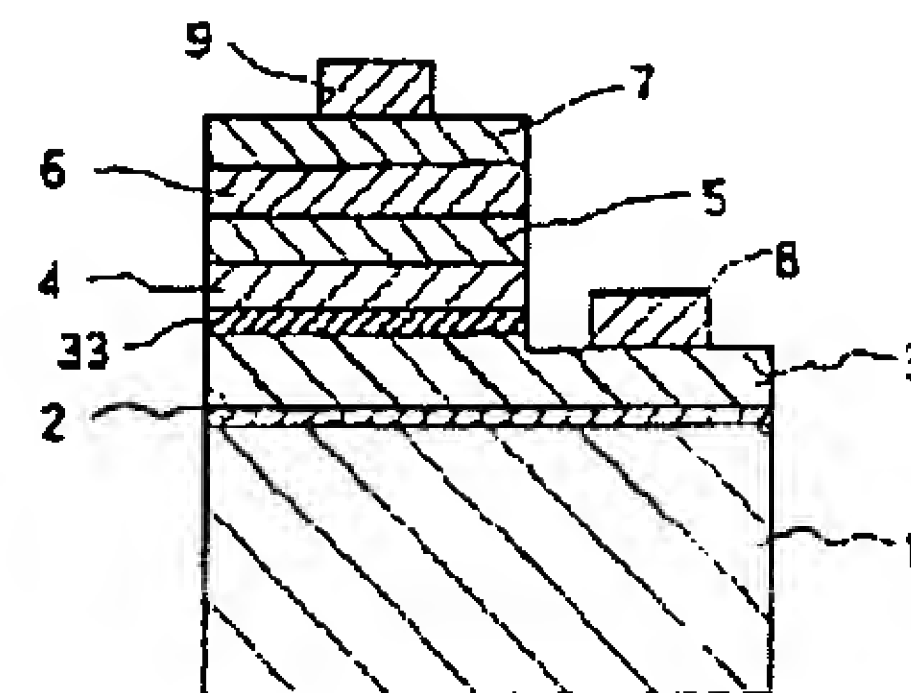
【図1】



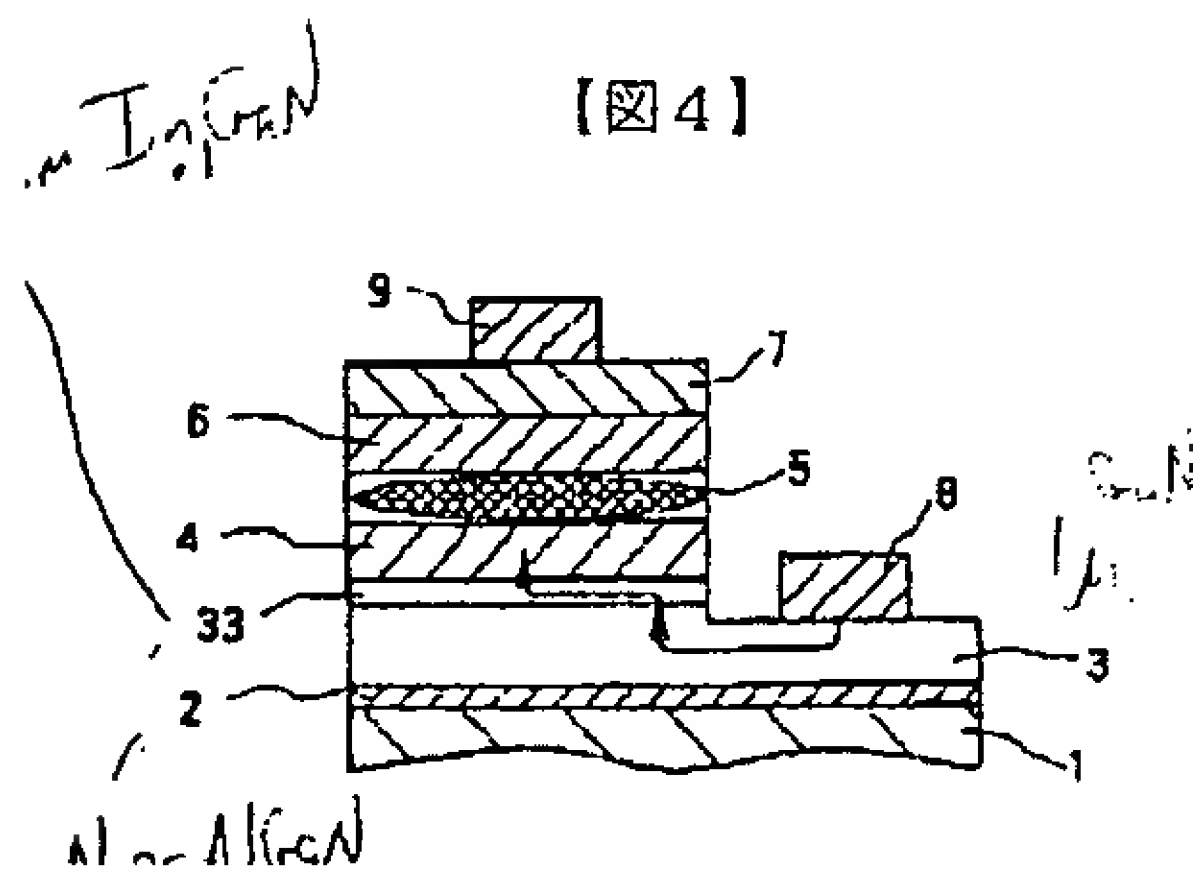
【図2】



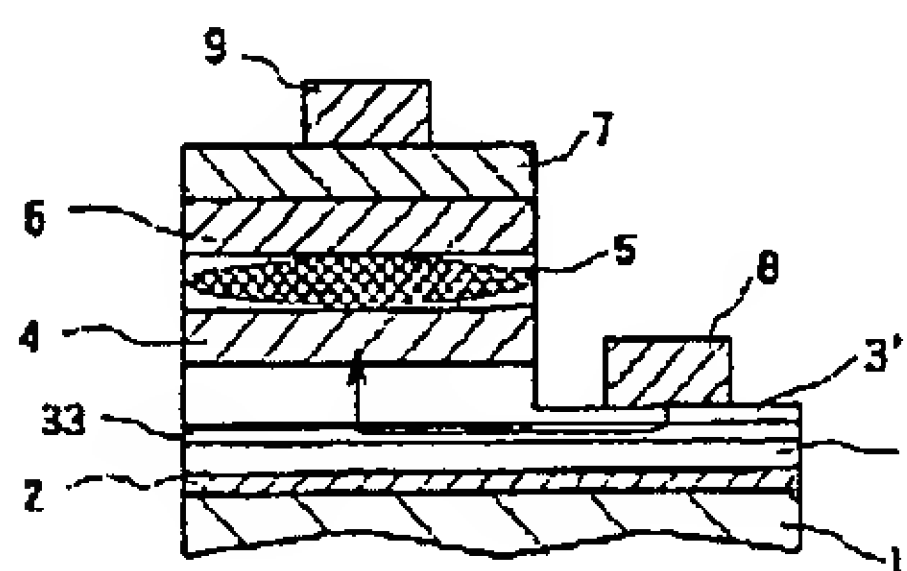
【図3】



【図4】



【図5】



【図6】

